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ADAPTATION AND APPLICATION OF A MODEL FOR PREDICTING WET SULPHUR DEPOSITION IN NEW BRUNSWICK

CEC J1773

Submitted to

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EXECUTIVE SUMMARY

Background

The review of the 1986 Environmental Impact Statement (EIS) for the proposed fuel conversion of the Coleson Cove Thermal Generating Station (TGS) to burn coal resulted in the stipulation that state-of-the-art wet deposition monitoring and modelling programs be established. These programs would provide reliable wet deposition monitoring data throughout the province and allow accurate prediction of the relative contribution of the Coleson Cove TGS to wet deposition levels in the Coleson Cove-Saint John airshed. In view of the linkage between the monitoring and modelling projects, a summary of the wet deposition monitoring which was the subject of a separate report (Davis, 1991) is presented here.

Wet Deposition Monitoring

Two wet deposition monitoring networks, the Coleson Cove Precipitation Monitoring Network (CCPMN) (12 stations) and the Expanded New Brunswick Precipitation Monitoring Network (ENBPMN) (6 stations) were established in May 1988. An independent external audit of the networks (field, laboratory and systems audit) was conducted by Concord Environmental. Analysis of the network data for the two year period June 1988 to May 1990 included intercomparisons of collocated samplers, statistical analyses of acid rain chemistry data as well as analysis of one year of daily back trajectory data from Harcourt, N.B..

The external audit and the intercomparison analyses provided evidence and firm reassurance that the data collected in one of the most spatially dense wet deposition monitoring networks in North America are reliable and of extremely high quality. Intercomparisons between the Canadian Air and Precipitation Monitoring Network (CAPMoN) and ENBPMN measurements at Harcourt indicated that the

relative biases were less than 10% for all species except chloride which was 12%. These low relative biases will not significantly affect the deposition estimates.

The measured seasonal and annual wet excess sulphate deposition levels were consistently higher in the Coleson Cove-Saint John area than in other areas of New Brunswick. Wet excess sulphate levels were generally higher in the second year than in the first. In contrast, precipitation weighted mean nitrate concentrations were generally lower in the second year than in the first. The seasonal variation of precipitation weighted mean nitrate concentrations and nitrate deposition showed distinctly higher levels in winter seasons at most stations, whereas the sulphate concentrations and deposition were less variable. Precipitation weighted mean concentration and deposition isopleths in the Coleson Cove-Saint John area showed the greatest variability and reflect the predominantly southeast/northwest wind patterns that occur in the Saint John area.

The back trajectory analysis showed that most of the deposition events originated from source regions to the west of the province (from areas in Quebec, Ontario and the northeastern U.S.) Some 18 trajectories from these areas were associated with 50% of the wet sulphate deposition and over 200 trajectories contributed 75% of the deposition in the one year period ending May 31, 1989. Significant numbers of trajectories originated from areas north and south of Harcourt but these were associated with low deposition events.

Modelling Program

A state-of-the-art model, MESOPUFF II, has been adapted for application to New Brunswick. MESOPUFF II is the dispersion model that was used in the Lagrangian Estimate of Regional Transport and Acid Deposition (LERTAD) system developed for the Canadian Electrical Association by Concord Environmental. LERTAD was applied to the entire eastern North American area. The adaptation for use in New Brunswick included collection of required emissions information for

sulphur dioxide sources in New Brunswick and also meteorological and land use data needed as model inputs. Extensive changes were made to the MESOPUFF II model in order to accept the different formats of meteorological data that are available from U.S. and Canadian sources.

Model estimates of wet sulphur deposition were predicted at locations (receptors) corresponding to the wet deposition monitoring stations. Since the model can handle a limited number of sources at a time, sulphur dioxide emission sources were segregated into four source groups namely, Coleson Cove alone (CC), New Brunswick south (NBS), and north (NBN) and out of province sources (OOP) which fall in the overall domain in areas adjacent to New Brunswick (eastern Maine, Nova Scotia and Quebec).

The model was successfully calibrated against the measured wet deposition data collected in the monitoring program. The calibration resulted in estimates of the background wet deposition (due to long range transport) that are reasonable and consistent with measurements at the remote sites and at sites in the Coleson Cove Saint John area. The comparison of observed and predicted (including the derived background) seasonal wet deposition was good based on the square of correlation coefficients (R^2) which ranged from 0.3 to 0.75 for 7 of 8 seasons. (Note that perfect correlation will yield R^2 values of 1.0.) More rigorous comparisons based on weekly time periods showed good correlations especially when the measured rainfall at the monitoring stations agreed within 25% of model input precipitation data.

The model estimates showed that the Coleson Cove TGS is predicted to contribute an average of 12.5% of the annual wet sulphur deposition (including background) at receptors in the Coleson Cove-Saint John area. The Coleson Cove TGS is predicted to contribute between 53% and 67% of the **incremental** wet sulphur deposition (i.e., all sources modelled and excluding the background) at receptors in the Coleson Cove Saint John area. Background wet sulphur deposition, defined

in this report to include the contributions due long range transport from outside the domain, is predicted to account for 80 to 85% of the annual wet S deposition.

The model results are considered very reliable for the following reasons. Sulphur dioxide emissions data are of excellent quality primarily because the majority (70%) of the emissions in the province are due to NB Power sources and the emissions data for NB Power sources are considered reliable. The data for the remaining sources are considered to be good and it is estimated that over 90% of the sulphur dioxide sources were accounted for in the model. The qualifications "very reliable" and "good" are subjective, but reflect professional judgement.

The precipitation data input to the model are cause for some concern but the analysis of the data took into consideration much of the discrepancy between the precipitation observed at wet deposition monitoring stations and that used in model input. Recommendations for improved application of the model to New Brunswick in the future include the use of available additional daily precipitation data at wet deposition monitoring stations and also inclusion of any updates to the emission information.

Model predictions for receptors close to the sources require further investigation as do the methods for estimating background wet deposition levels in areas with a high background relative to local sources.

The model will allow reliable estimates of wet deposition throughout the province of New Brunswick as sulphur emission reduction programs and the NOx/VOC management plans are implemented over the next several years. Recommendations for application of the model to meet future NB Power and provincial requirements have been presented.

1 INTRODUCTION

In 1986, NB Power completed an Environmental Impact Assessment (EIA) for the proposed fuel conversion of the oil-fired Coleson Cove Thermal Generating Station (TGS) to burn coal. Arising out of the review of the EIA document were requirements to establish a more extensive and reliable wet deposition monitoring network in the Coleson Cove-Saint John area and also to extend the existing provincial wet deposition monitoring network. The monitoring program was to precede a regional scale model adaptation and validation study that would provide a reliable estimation of the contribution of the Coleson Cove TGS to wet deposition levels in the Coleson Cove-Saint John airshed and also to allow the prediction of wet deposition levels throughout the province.

Wet deposition monitoring had been conducted at four stations in the Saint John Precipitation Monitoring Network since 1984. The measured wet deposition levels in the Saint John area were extremely high and the presence of sensitive watersheds, especially in the Musquash and Lepreau areas to the west of Saint John and the catchment area for the City of Saint John to the east of the city, were cause for concern. Annual excess sulphate wet deposition measured at stations in the now defunct Saint John Precipitation Monitoring network ranged from 15 to 35 kg SO_4/ha/y in 1985 and 1986. However, there were concerns over the quality of the monitoring data (Davis et al., 1987).

Wet deposition monitoring methods have been improved considerably since the establishment of the Saint John Precipitation Monitoring network and the revamping of the network to employ current monitoring protocols would ensure the acquisition of the most reliable data. NB Power funded the establishment of the Coleson Cove monitoring network and provided additional support to complement the revamping of the expanded provincial network. Costs for operating the networks were shared by the New Brunswick Department of Municipal Affairs and Environment (now the Department of the Environment) and NB Power. Since May

1988, wet deposition monitoring throughout the Province of New Brunswick has been carried out over two networks: the Coleson Cove and the Expanded New Brunswick Precipitation Monitoring networks. These networks were established as a result of conditions specified in a review of the Environment Impact Assessment (EIA) document (NB Power, 1986) for the proposed conversion of the oil-fired Coleson Cove TGS to coal as fuel.

It should be noted that the provincial network was coordinated by a Department of the Environment staff member and the Coleson Cove Network was coordinated by a NB Power staff member. Each network coordinator provided QA/QC functions for the other network. All chemical analyses were conducted by Department of the Environment laboratories as were the data acquisition and compilations. An independent external audit of the networks (field, laboratory and systems audit) was conducted by Concord Environmental (Davis et al., 1989).

Another requirement of the EIA was the establishment of a modelling program to provide reliable estimates of wet sulphate deposition loadings in the Coleson Cove-Saint John area as well as throughout the entire province. Both local (from the city of Saint John and Coleson Cove TGS) and distant (via long range transport) sources are likely to contribute to the observed wet sulphate deposition levels but the relative contribution from each of these sources is unknown. A state-of-the-art modelling program in conjunction with the two year monitoring program was commissioned to Concord Environmental to provide a validated model that would provide reliable estimates of wet deposition throughout the province.

The modelling system proposed was the LERTAD (**L**agrangian **E**stimates of **R**egional **T**ransport and **A**cid **D**eposition) system, which was developed for the Canadian Electrical Association (Fung et. al., 1987). The LERTAD system employs MESOPUFF II which is a long range transport model which was deemed to be the best available model after an extensive review of available Lagrangian

models (Fung et al., 1985). LERTAD was initially developed to simulate deposition over eastern North America. The LERTAD system included the compilation of input data for eastern North America and the development of preprocessor and post processor programs for data management and statistical analysis. LERTAD was implemented and run to simulate wet deposition and SO_2 concentrations over eastern North America for a two week period during July 1980 (Fung et al., 1987).

The model adaptation envisioned for this study (Davis et al., 1987) required implementation of the MESOPUFF II model for New Brunswick by collection and processing of model input data with subsequent model validation. The validated model would then be suitable for future application in New Brunswick. The model validation contemplated included sensitivity tests on the first of two years data in order to select suitable model input parameters, i.e., to calibrate the model. The calibrated model would then be run and compared against the second years data without further adjustment of model parameters.

In view of the extensive sensitivity analyses conducted for MESOPUFF in earlier studies, only selected parameters and conditions were used in the current sensitivity analyses to determine the most suitable input parameters. The sensitivity runs were conducted for selected seasons in the first year and predictions were made for the second year. Analysis of the model predictions dictated a different course of action which resulted in the use of a season-specific background for all eight seasons.

1.1 PROJECT OBJECTIVES

The objectives of the study are as follows:

- to determine the relative contribution of the Coleson Cove TGS to wet sulphur deposition levels in the Coleson Cove-Saint John area, and

- to provide a model that can be applied throughout the province of New Brunswick in order to determine impacts of changes in sulphur emissions on wet and dry deposition levels throughout the province.

This report describes the results of the model adaptation and the application of the model in order to meet the objectives indicated above.

1.2 REPORT STRUCTURE

The MESOPUFF model is described in Section 2 with additional details of the modelling system used in this study provided in Appendix 1. The methodology used to conduct the modelling is described in Section 3 as are the model input requirements. Model predictions are presented and discussed in Section 4. Conclusions and recommendations are presented in Section 5. References are listed in Section 6.

2 TECHNICAL DESCRIPTION

The MESOPUFF II modelling system is described in this section. The modelling system is available as a personal computer (PC) version with an executable file compiled for a 80286 PC. The model consists of three modules, namely, a meteorological preprocessor, MESOPAC II, the dispersion model, MESOPUFF II, and a post processor, MESOFILE II. Limited use was made of the MESOFILE II system since customised post processing was required for the current study. The following sections describe the MESOPAC II and MESOPUFF II models.

2.1 MESOPAC II METEOROLOGICAL MODEL

The MESOPAC II meteorological model computes hourly winds at two vertical layers for each grid point. The lower layer winds are used to advect puffs within the mixed layer and to determine the plume rise of newly released puffs. The upper layer winds transport material released above the mixing height. In the current application, the vertically averaged mixed-layer winds were used for the lower layer wind field. The vertically averaged winds in the layer from the top of the mixing height to the 700 mb pressure level (approximately 3000 meters) were used for the upper layer wind field.

Both twice-daily rawindsonde data from upper air stations and hourly surface wind observations from the typically much denser network of surface stations are used by MESOPAC II in the computation of the mixed layer winds. The interpolation method, adapted from Draxler (1979), first obtains the surface winds at each grid point using inverse distance squared weighting and wind direction alignment factors. Vertically averaged winds through the mixed-layer are then calculated at the rawindsonde stations using representative soundings (0000 or 1200 GMT). The ratio of wind speed and difference in wind direction between the mixed layer averaged wind and the surface wind at the rawindsonde station are used to adjust the surface winds at each grid point. This method allows the vertical information contained in the upper air soundings to be combined with the better space and

time resolved surface observations in the development of the lower layer wind field.

The computation of surface friction velocity, u_*, is based on the method of Wang and Chen (1980) during unstable conditions and that of Venkatram (1980a) during stable conditions; u_* is determined from wind speed, surface roughness and heat flux.

The daytime surface sensible heat flux, H, is estimated with the following relationship (Maul, 1980):

$$H = 950\ \alpha\ \beta\ (\sin\theta) + H_o \qquad [2\text{-}1]$$

where H is W/m^2, H_o is the sensible heat flux in the absence of incoming solar radiation, θ is the solar elevation angle, α is a land use constant (~0.35), and β is a radiation reduction factor due to the presence of clouds (β ranges from 0.23 with overcast conditions to 1.00 with clear skies).

During daytime hours, the Monin-Obukhov length is calculated directly from its definition using the values of the friction velocity and heat flux obtained above:

$$L = -\frac{u_*^3\ T_o}{(g\ k\ Q_o)} \qquad [2\text{-}2]$$

$$Q_o = \frac{H}{(\rho\ c_p)} \qquad [2\text{-}3]$$

where T_o is the air temperature, g is the acceleration due to gravity, k is the Von Karman constant, and ρ is the air density, and c_p is the specific heat of air at constant pressure.

At night, the empirical relationship recommended by Venkatram (1980b) is used to compute the Monin-Obukhov length:

$$L = 1100\ u_*^2 \qquad [2\text{-}4]$$

During the daytime, solar radiation heating the ground results in a positive (upward) flux of sensible heat. This heat flux causes a well-mixed adiabatic layer to develop. The hourly variation in the surface heat flux, determined from Equation [2-1] is used to estimate the height of the mixed layer in a step-wise manner (Maul, 1980):

$$(z_i)_{t+1} = \left[(z_i)_t^2 + \frac{2Q_o\,(1+A)\,\delta t}{\Phi} - \frac{2(\delta\theta)_t\,(z_i)_t}{\Phi}\right]^{1/2} + \frac{(\delta\theta)_{t+1}}{\Phi} \qquad [2\text{-}5]$$

$$(\delta\theta)_{t+1} = (2\,\Phi\;A\,Q_o\,\delta t)^{1/2} \qquad [2\text{-}6]$$

where Φ is the temperature lapse rate above the mixing height, A is a constant (0.15), $\delta\theta$ is the temperature discontinuity at the top of the mixed layer, t is the time and δt is the duration over which the change in mixed layer height is being calculated. Mechanically generated turbulence determines the vertical extent of dispersion during stable conditions. Venkatram (1980) estimates z_i during these conditions as:

$$z_i = 2400\,u_*^{3/2} \qquad [2\text{-}7]$$

2.2 MESOPUFF II DISPERSION AND DEPOSITION MODEL

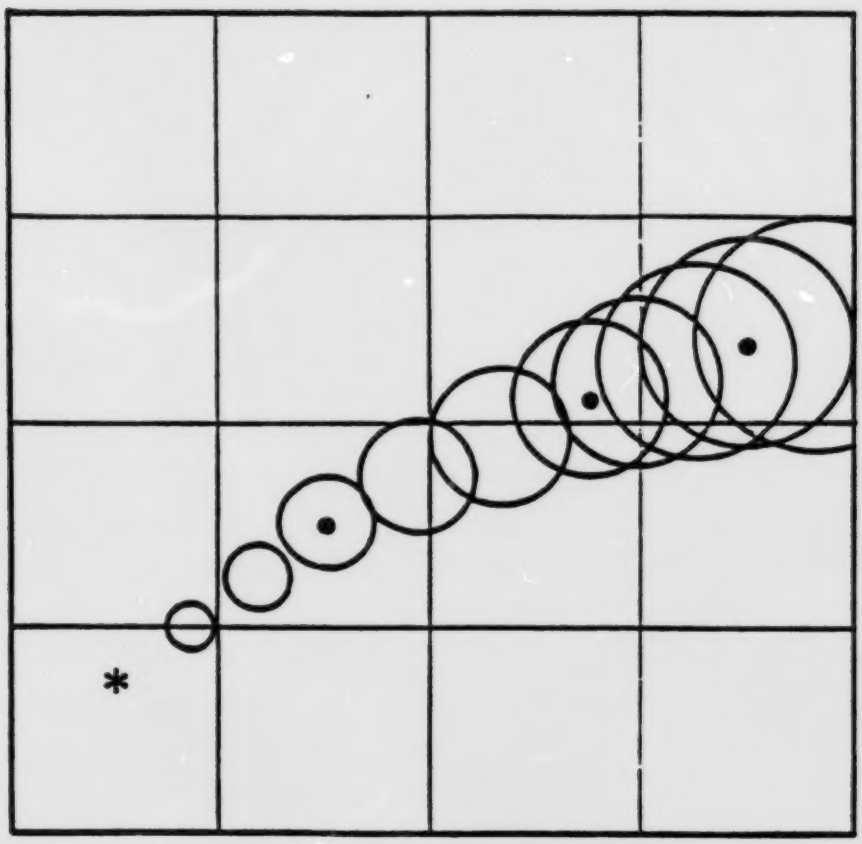
As illustrated in Figure 2-1, the MESOPUFF II model simulates a continuous plume as a series of discrete puffs. The trajectory of each puff is determined independently of preceding or succeeding puffs, and is subject to space- and time-varying wet removal, dry deposition, and chemical transformation. In this section, the puff sampling, chemical transformation and removal algorithms are outlined. The model is more completely described in Scire et al. (1984a, b).

The concentration due to a horizontally symmetric puff with a Gaussian distribution is:

$$C = \frac{Q\,g_v}{2\,\pi\,\sigma_y^2}\;\exp\left[\frac{-r^2}{2\,\sigma_y^2}\right] \qquad [2\text{-}8]$$

FIGURE 2-1

Schematic Representation of the Puff Superposition Approach



$$g_v = \frac{2}{(2\pi)^{1/2}\,\sigma_z} \sum_{n=-\infty}^{\infty} \exp\left[-\frac{(H_e + 2nz_i)^2}{2\,\sigma_z^2}\right] \qquad [2\text{-}9]$$

where C is the ground level concentration, Q is the mass of the pollutant in the puff, σ_y is the standard deviation of the Gaussian distribution in the horizontal, σ_z is the standard deviation of the Gaussian distribution in the vertical, r is the radial distance from the puff centre to the receptor, H_e is the effective height of the puff centre and n is the number of puffs.

In MESOPUFF II, Equation [2-8] is integrated over the distance the puff travels in a time step, δt, to determine the contribution of the puff to the receptor;

$$C(r, s) = \frac{1}{\delta s} \int_{s}^{s+\delta s} \frac{Q(s)\, g(s)}{2\pi\,\sigma_y^2} \exp\left[-\frac{r^2}{2\,\sigma_y^2}\right] ds \qquad [2\text{-}10]$$

where s is the total distance travelled by the puff, and δs is the distance travelled during the sampling time step. A computationally efficient analytical solution of Equation [2-10] is evaluated for each puff-receptor combination to determine the total concentration.

Once a puff is released from a source, three processes act to modify the amount of pollutant mass remaining in the puff: chemical transformation, dry deposition, and wet removal. The transformation rate of SO_2 to sulphate is treated as a first-order chemical reaction. MESOPUFF II uses linear transformation rates based on a statistical analysis of the results of a photochemical box model employing the RHC/NO_x/SO_x chemical mechanism of Atkinson et al. (1982). The empirical transformation rate depends on environmental conditions such as solar radiation, background ozone concentrations, atmospheric stability, and relative humidity. During daytime hours, the SO_2 to sulphate conversion rate is:

$$k_1 = 36\, R^{0.55}\, OZ^{0.71}\, S^{-1.29} + 3\times10^{-3}\, RH^4 \qquad [2\text{-}11]$$

where k_1 is the conversion rate in percent/hour, R is the total solar radiation (kW/m^2), OZ is the background ozone concentration (ppm), S is an atmospheric stability index ranging from 2 for unstable conditions to 6 for stable conditions, and RH is the relative humidity (percent).

The rate at which pollutants are deposited at the surface due to dry deposition depends on the characteristics of the pollutant, the underlying surface, and atmospheric conditions. In MESOPUFF II, a resistance model is used to determine the dry flux. The deposition velocity v_d, defined as the ratio of the pollutant flux at a reference height to the concentration at that height, is expressed as the inverse of a sum of resistances to pollutant transfer through the atmosphere to the surface.

$$v_d = (r_a + r_s + r_c)^{-1} \qquad [2\text{-}12]$$

In Equation [2-12], v_d is the deposition velocity, r_a is the atmospheric resistance, r_s is the surface resistance, and r_c is the canopy resistance. The atmospheric and surface resistances are expressed (Wesely and Hicks, 1977) as:

$$r_a = (k\, u_*)^{-1} \; [\ln(z/z_o) - \phi_h] \qquad [2\text{-}13]$$

$$r_s = (k\, u_*)^{-1} \; kB^{-1} \qquad [2\text{-}14]$$

where ϕ_h is a stability correction factor, z_o is the surface roughness length, k is Von Karman's constant and B^{-1} is a surface transfer function. The term kB^{-1} is approximately 2.6 for SO_2 (Wesely and Hicks, 1977). The SO_2 canopy resistance is a function of the amount, type, and state of the vegetation. MESOPUFF II allows different values of r_c to be specified for each grid point for four atmospheric stability regimes (unstable, neutral, stable, and very stable) to reflect diurnal and land use variations. Owing to the importance of the surface resistances to the modelling of dry deposition and the large uncertainty in the values, a sensitivity analysis for the canopy resistance values was conducted to determine the most appropriate values for this parameter (see Section 3.2.1).

For particulate matter, the surface resistance is a complex function of many factors, including particle inertia and gravitational settling (Sehmel, 1980). A typical value of the surface resistance of approximately 10 s/cm is used for sulphate. Uptake of particulate matter by plant stomata is not an important pathway; therefore, total resistance for sulphate is determined by r_a and r_s.

Under stable atmospheric conditions, the rate of dry deposition at the surface can sometimes be limited by the rate of pollutant transfer through the boundary layer to the surface layer. This overall boundary layer resistance is not accounted for in r_a. MESOPUFF II treats this surface depletion effect by including three vertical layers. The lowest layer is a shallow surface layer (~10 m) next to the ground that rapidly adjusts to changes in surface conditions. The middle layer extends from the top of the surface layer up to the mixing height, and the top layer consists of pollutant material above the mixing height. The pollutant flux, F, into the surface layer is:

$$F = K (C_m - C_s)/(z_i - z_s) = v_d C_s \qquad [2\text{-}15]$$

where K is an overall boundary layer diffusivity, C_m is the concentration in the middle layer, C_s is the concentration in the surface layer, and z_s is the surface layer height. During convective conditions, $K = 0.1\ w_* z_i$, and during stable conditions, $K = 0.01\ u_* z_i$ (Brost and Wyngaard, 1978) where w_* is the convective velocity. Because only pollutant material in the surface layer can be deposited, the flux into the surface layer serves as an upper limit to the rate at which the non-surface layer pollutants can be removed.

The term $v_d C_s$ in Equation [2-12] can be written as $v'_d C'_m$, where v'_d is an effective deposition velocity taking boundary layer mass transfer into account.

$$v'_d = \frac{K v_d}{K + v_d (z_i - z_s)} . \qquad [2\text{-}16]$$

TABLE 2-1

Scavenging Coefficients for SO_2 and $SO_4^=$

POLLUTANT	LIQUID PRECIPITATION	FROZEN PRECIPITATION
SO_2	3×10^{-5}	0.0
SO_4	1×10^{-4}	3×10^{-5}

Precipitation scavenging can be an efficient removal mechanism, especially for particulate pollutants such as sulphate that serve as cloud condensation nuclei. Wet removal of soluble and reactive pollutants such as SO_2 can also be rapid under some conditions. In MESOPUFF II, an empirical scavenging coefficient scheme is used to parameterize wet removal. The pollutant mass, Q, at the end of a time step of length δt, is:

$$Q(t + \delta t) = Q(t) \exp [- \Gamma \delta t R/R_1] \qquad [2\text{-}17]$$

where Γ is the scavenging coefficient, R is the precipitation rate, and R_1 is a reference unit precipitation rate. Table 2-1 summarizes the scavenging coefficients for SO_2 and $SO_4^=$. Different scavenging rates are used for liquid and frozen precipitation to simulate, in a simple way, the effects of different precipitation formation mechanisms. Slinn et al. (1978) note that snow scavenging of gases is generally negligible. The scavenging coefficient for SO_2 and sulphate removal by rain is based on Maul (1978) and Garland (1978). The wet removal rate of sulphate by snow is derived from Maul (1980).

3 METHODOLOGY

The execution of the project required selection of computer hardware, and determination of the model adaptation, validation and application schemes to be used. The approaches used are described in this section.

3.1 COMPUTER HARDWARE

The adaptation of the LERTAD model to New Brunswick involved a radical departure from the system employed by LERTAD (Fung et al., 1988). Consideration of the advances in computer technology and the costs involved in running the model pointed to the use of personal computers (PCs) rather than the CYBER 205 mainframe used previously for LERTAD, as the system for conducting this project. The flexibility, convenience and cost reductions provided by PCs far outweighed the reduced speed for execution. Furthermore, anticipated advances in PC technology are expected to lower the difference in execution speed between PCs and mainframe to more acceptable levels. Indeed, since the start of the project we have seen the introduction of 486 PCs which have provided additional speed enhancements that were realised in the project. The modelling was planned for implementation on a 25 MHz 386 PC with a Weitek coprocessor. This system was shown to offer over three fold improvement in execution speed over a similar system with a 80387 coprocessor. Towards the end of the project, a 25 MHz 486 computer with a Weitek coprocessor was employed.

A PC version of MESOPUFF II including the fortran source code was acquired and the necessary source code changes were made to allow compilation using a 386 compiler. Test data supplied with the model were used to validate the 386 compiler by running the 286 and 386 compiled executable versions using the same input data. Identical results were obtained.

3.2 MODELLING APPROACH

Given the demanding data storage and computational requirements of the model, the strategy focused on minimizing the number of runs within the limitations imposed by the computer hardware and the model formulation. This was accomplished by performing runs on a seasonal basis with the minimum number of source groups. Model formulation includes the use of some seasonally dependent input variables hence the segmentation of model runs on a seasonal basis is natural. Therefore, it was convenient to limit the periods modelled to one season at a time in view of the data storage requirements especially for input meteorological data and the seasonal variation of selected model inputs. The seasons were meteorological seasons defined as follows: summer as June, July and August; fall as September, October and November; winter as December, January and February and spring as March, April, May. Eight seasons were defined starting with the summer of 1988. For each model run, the period modelled included at least one additional week before the beginning of the first Tuesday in each season in order to allow the model to avoid start up effects. Data from the wet deposition monitoring networks are obtained over one week periods hence the hourly predictions output by the model were summed or averaged over one week time periods which coincided exactly with the monitoring period (1 week starting each Tuesday at 0800 local time).

The model adaptation comprised the development and adaptation of appropriate preprocessor programs to handle meteorological data and the compilation of the meteorological emissions (source) and land use data. Changes to the source code of the MESOPUFF II model were implemented also. The analysis of the model predictions is particularly complex in the current situation since the model domain is subject to a very high level of background wet deposition.

The required meteorological data included both U.S. and Canadian data. Several changes in the formats of the U.S. data have occurred since the LERTAD scheme was developed and this resulted in the expenditure of considerably more effort

than was anticipated in executing this aspect of the adaptation. Details of the required changes are provided later (Section 3.3.1).

The model adaptation also included an investigation of the suitability of selected model input parameters thus sensitivity runs were performed. A two tiered approach was adopted in the sensitivity runs. The first involved the selection of model input parameters for sensitivity tests and performing model runs for a one week period to establish which variables would be most appropriate for more detailed investigation. The variables selected were then used in model runs for selected seasons for comparison with monitoring data from the first of the two years during which monitoring data are available.

3.2.1 Sensitivity Tests

The model inputs to MESOPUFF are segregated into 16 "Card Groups". Each Card Group was examined in order to select variables for consideration in the sensitivity tests. Previous studies that included the sensitivity tests of the MESOPUFF model input parameters were reviewed to assist in the selection of parameters that seemed likely to affect wet deposition levels (Fung et al., 1988; State of Minnesota, 1985). Based on the review of previous sensitivity tests, seven parameters were selected for further scrutiny. A list of the variables reviewed and considered for scrutiny is shown below. The seven variables selected for sensitivity testing have the range of values (relative to the default values taken as 100%) indicated in the tabulation. A summary of the tier 1 sensitivity tests is given in Appendix 2. The sensitivity tests were run for 1 week in 1988 and the total sulphur deposition was calculated at 31 receptors. The response of the predicted S deposition to the various levels of the variables was examined only for those cases where the predicted deposition was greater than 0.01 kg S/ha (see Appendix 2). The response of the predicted deposition was negligible (<10%) for variation of the AGEMIN, CO3B and RNITE. The variation of S deposition with various levels of WA1 (the washout ratio for liquid precipitation) was inconsistent for the stations near to Coleson Cove. The S

VARIABLE	DESCRIPTION	RANGE (%)		
NSAMAD	Minimum sampling rate	50	100	200
WSAMP	Reference wind speed used with LVSAMP	50	100	200
AGEMIN	Minimum age of puffs to be sampled	50	100	200
TMDEP	Distance beyond which time dependent dispersion equations are used			
RCSO2	SO_2 Canopy resistance	25	50	75
		100	150	200
RSGCON	SO_2 surface resistance for gases	50	100	200
RSPART	$SO_4^=$ Canopy resistance			
WA1	Washout coefficient (liquid)	50	100	200
WA2	Washout coefficient (frozen)			
CO3B	Background O_3 concentration			
RNITE	Nighttime SO_2 loss rate	50	100	200
AREAHT	Area source effective height			
AREASY	Area source initial horizontal dispersion			
AREASZ	Area source initial vertical dispersion			

deposition predictions varied by -100% to +300% relative to the base case for changes in WA1 ranging from 50 to 200% of the base case (see Appendix 2). Similarly, inconsistent and inexplicable responses were shown for NSAMAD and WSAMP, but the variation was often less marked on doubling these variables from 100 to 200% of the base values (S deposition decreased by about 20% for 5 of 6 stations see Appendix 2). Changes in RCSO2 were generally consistent (for all but one case -see Appendix 2), in that the S deposition increased with increasing RCSO2.

Based on the tier 1 sensitivity tests, more extensive (tier 2) sensitivity/validation tests were run using only one variable, namely, RCSO2, the SO_2 canopy resistance. The values for the canopy resistances for SO_2 were selected after consideration of the default values and those in the State of Minnesota report (1985). The resistances are dependent on land use category and on season.

Values of these parameters for spring and fall are similar and thus the same resistances were used for spring and fall. Model sensitivity runs were performed for three of the four seasons in year 1, i.e., for summer 1988, winter 1988/89 and spring 1989 using three levels of values for the canopy resistance for SO_2. Two of the four source groups were used (Coleson Cove and New Brunswick south) since between them they accounted for over 80% of the predicted incremental wet sulphur deposition.

Comparison of the predictions for the winter of 1988/1989 were poor and it was felt that the major factor in the poor results was the very poor agreement between the observed precipitation at monitoring stations and the hourly (summed to each week) precipitation data used in the model inputs. Further investigation of the raw data showed that the hourly measurements only include precipitation falling as rain and excludes snow. Fortunately, the hourly records do contain a flag indicating whether or not precipitation fell and the type of precipitation even if (as in the case of snow) the precipitation amount for the hour is missing. Consequently, daily precipitation records were examined for each station and the daily precipitation was allocated evenly to those hours which had a precipitation flag and missing precipitation amounts.

In the absence of an alternate basis to allocate the precipitation to the hours with snow, the even allocation is the most reasonable. It should be noted that since the minimum time over which wet deposition is averaged is one week, even allocation of the daily precipitation amount to hours with the precipitation flag is not expected to have a significant impact on model predictions. The scheme was applied to the winter seasons. Sensitivity runs for the winter 1988/1989 season were repeated using the revised precipitation data. Considerable improvement in the comparison between the measured precipitation and the model input data was achieved.

3.2.2 Source Code Changes

Several changes were made to the source code for MESOPUFF II. Various arrays throughout the program (MESOPUFF) were changed in order to allow a larger number of sources to be modelled in a run. The number of sources in a run is limited by the number of individual puffs that must be tracked while in the model domain. It was found that the initial model formulation allowed only about 7 sources to be modelled (the precise number of sources is dependent on source characteristics and meteorology). The changes made allowed up to about 30 sources to be modelled in a single run. This allowed four source groups to be modelled (Coleson Cove alone, southern New Brunswick, northern New Brunswick and out of province sources). Details of the source code changes are provided in Appendix 1.

3.2.3 Background Wet Deposition

The modelling inputs included point and area sources in the model domain which included all of New Brunswick as well as parts of Maine, Quebec and Nova Scotia. In the case of sources in the Maine, Quebec and Nova Scotia, only the larger point sources were included. Because of natural emissions of reduced sulphur compounds that get oxidized to sulphur dioxide and also because of long range transport of sulphur dioxide and sulphates into the model domain, there will be wet deposition in the model domain from these sources which are not included in the model. The wet deposition due to these sources (natural background and long range transport) is, for the purposes of this report, defined as the background wet deposition.

Background wet deposition is expected to vary spatially due to concentration gradients in the natural and long range transported sulphur species and also due to the amount of precipitation. The spatial variation of precipitation is expected to be the larger of the two factors thus a method (to estimate the background wet

deposition) that incorporates the wet deposition variability due to precipitation, was sought.

Two methods were considered for selecting the background wet deposition. Firstly, model predictions of wet sulphate deposition for the grid squares over New Brunswick from the SERTAD model (Fung et al., 1988) were to be used as the background. The second method considered was to develop a relationship between the observed wet deposition and the predicted deposition at each monitoring station via:

- using the intercept of a plot of observed sulphate deposition against predicted deposition, or
- calculation of the mean difference between the observed deposition and the predicted deposition at selected groups of stations.

Use of model predictions from SERTAD was ruled out for two reasons. Firstly, suitably formatted current emissions inventory data (for 1985) were not readily available and thus model predictions using 1985 emissions could not economically be conducted since reformatting of the raw 1985 emissions inventory data into a format suitable for SERTAD would be a major exercise. Secondly, inclusion of out of province sources would involve some amount of double counting if SERTAD estimates were included. The second method of accounting for background wet deposition levels was adopted. Further discussion of this aspect is presented in Section 4.

3.3 MODEL INPUTS

Four types of input data are required to drive the MESOPUFF II model and its preprocessors. They are:

1. meteorological data
2. source and emissions data

3. land use data
4. run control parameters

The model domain and the time period modelled must of course be specified. The model domain and the four types of input data are discussed in the following sections.

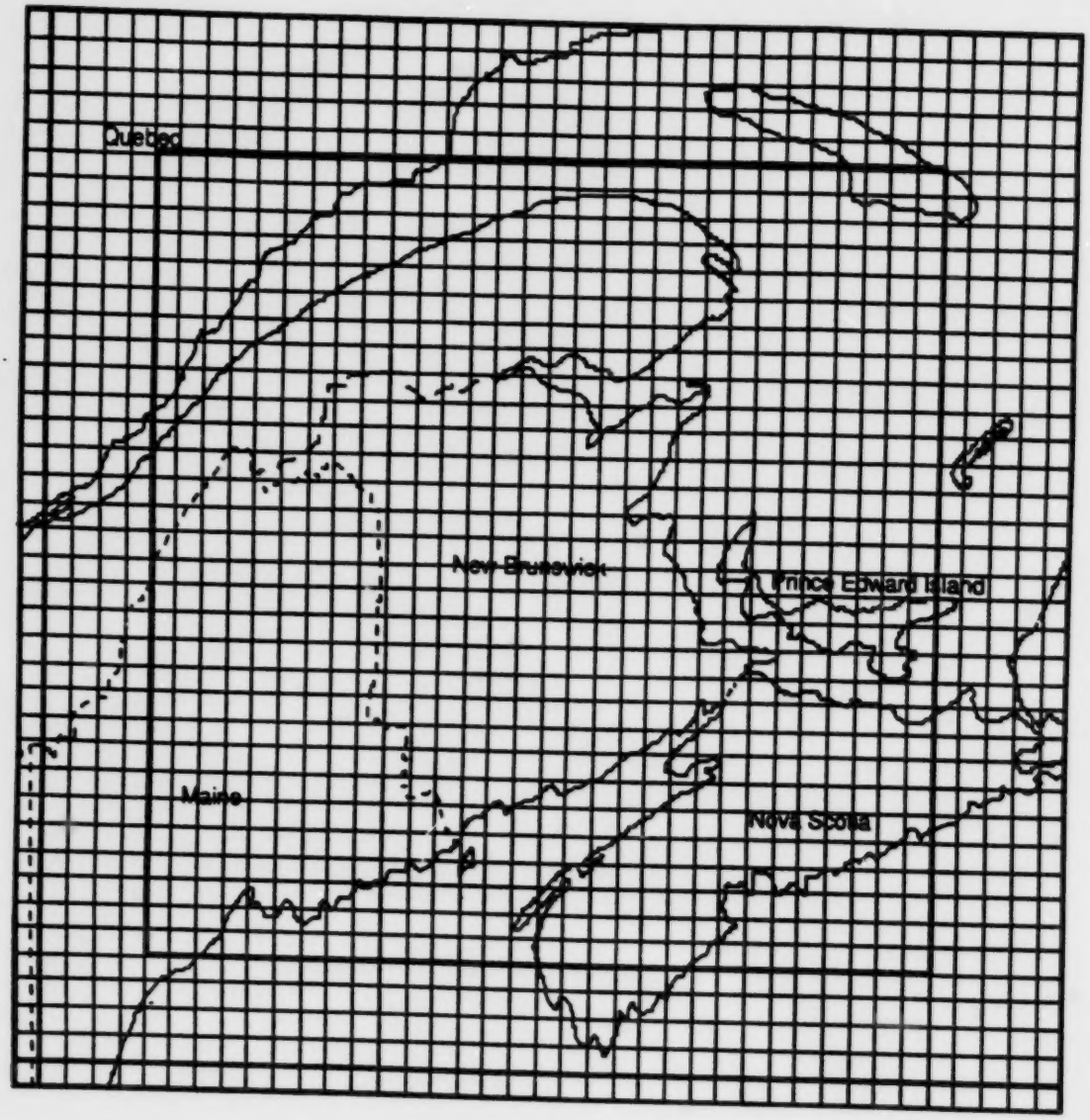
3.3.1 Coordinate System

Three Cartesian grid systems need to be specified as part of the definition of the modelling domain and receptor network: a meteorological grid, a computational grid, and a sampling grid. The meteorological grid determines the points at which the wind field and micrometeorological parameters (e.g., friction velocity, Monin-Obukhov length) are computed by the MESOPAC II meteorological model. The computational grid is the domain in which puffs are emitted, advected, undergo chemical transformation, and are depleted by wet and dry removal processes. The computational grid must contain all the sources modelled. It must be identical to or be a subset of the meteorological grid. The sampling grid defines the set of gridded receptors at which concentrations and fluxes are computed by the model. In addition, non-gridded receptors may be placed at discrete points within the computational grid. Since puffs located off the computational grid are not tracked by the model, and therefore do not contribute to concentrations or fluxes at receptors, the sampling grid and discrete receptors should be an internal subset of the computational grid.

The basic modelling domain and grid systems selected are shown in Figure 3-1. The meteorological grid and computational grid are identical, with 40 x 40 grid squares each 20 km square. A sampling grid of 31 x 31 points is contained within the computational grid starting at grid cell (5,5). In addition, non-gridded receptors were located at the monitoring stations and at other selected locations. The locations of the non-gridded receptors are shown in Figure 3-2. Due to excessive

FIGURE 3-1

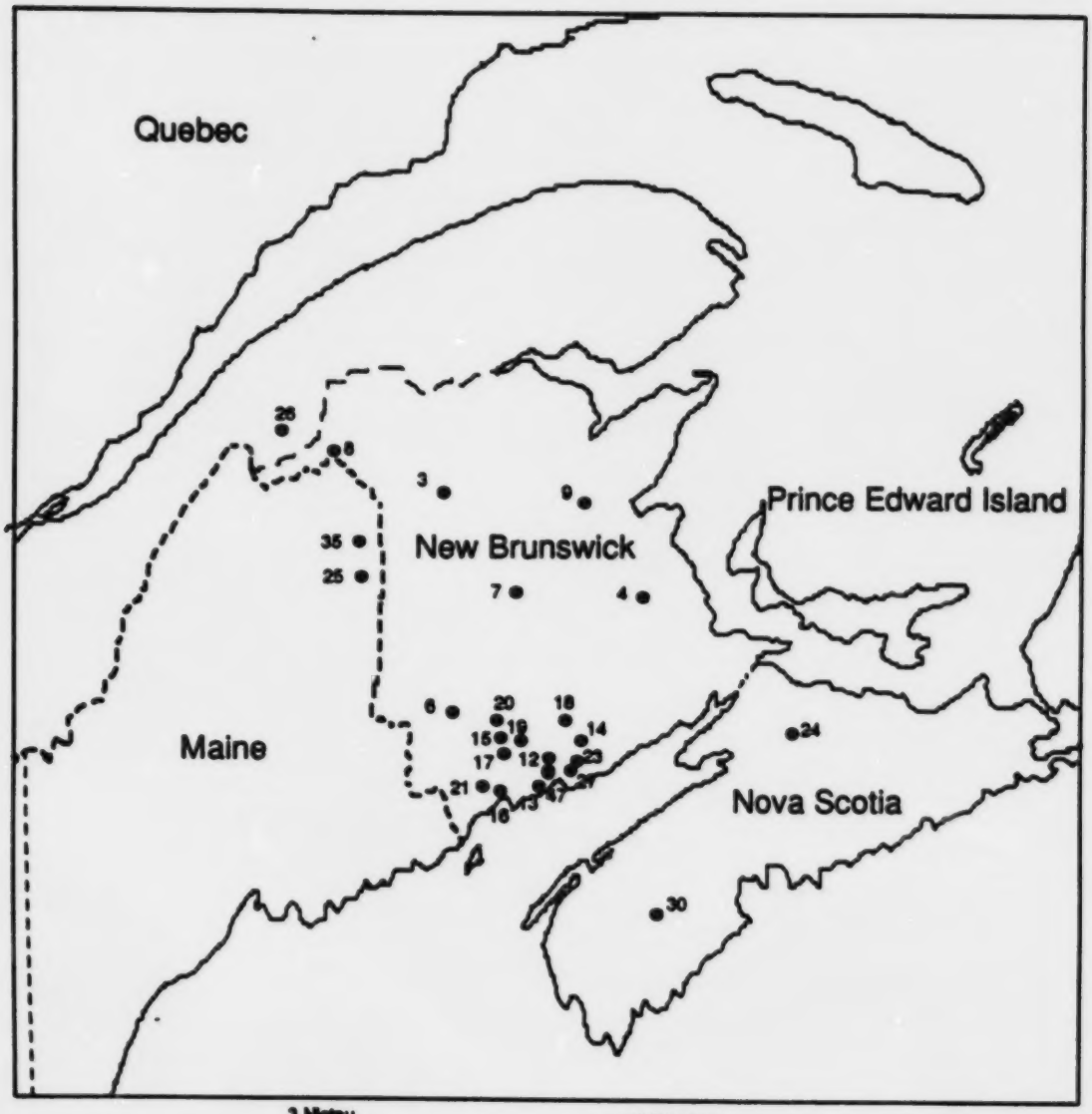
Modelling Domain and Grid Systems



Outer Grid, 40 x 40 Grid Points: Meteorological and Computational Grids
Inner Grid, 31 x 31 Grid Points: Sampling Grid

FIGURE 3-2

Locations of Non-Gridded Receptors



3 Nictau
4 Harcourt
6 Magaguadavic Lake
7 Holtville
8 Second Falls
9 Trout Brook
12 Lonewater Farm
13 Musquash
14 Darling's Island
15 Juvenile Settlement
16 Pennfield
17 South Oromocto Lake
18 Shannon
19 Wirral Station
20 Tracy
21 Bonny River
23 Golden Grove
24 Jackson
25 Presque Isle
26 Notre-Dame-du-Lac
27 Lakewood Heights
30 Kejimkujic
35 Caribou
47 Grand Bay

CONCORD
ENVIRONMENTAL

computational requirements for modelling each point on a 31 x 31 grid, it was decided to model only the receptor locations.

Two full years were modelled starting from June 1988. Model runs were performed for each of 8 seasons starting with summer 1988. The initial hourly outputs of wet SO_2 and $SO_4^=$ depositions were used to compute the weekly and seasonal wet sulphur deposition at each receptor.

3.3.2 Meteorological Data

The categories of meteorological data required are twice daily upper air, hourly surface and hourly precipitation data. Meteorological data from a wide area including Maine, New Brunswick, Nova Scotia, Quebec and Prince Edward Island were compiled. The stations from which meteorological data were collected are listed in Table 3-1. A total of four upper air stations, fourteen surface stations and thirteen precipitation stations were finally selected. The locations of these meteorological stations are shown in Figure 3-3. For the U.S. stations, the meteorological data were provided by National Climatic Centre (NCC) in Asheville, North Carolina, and for the Canadian stations they were provided by Atmospheric Environment Service (AES) in Downsview, Ontario.

The modelling package includes the meteorological preprocessing program, READ56, and the meteorological model, MESOPAC II, for preprocessing the meteorological data. It extracts the pressure, height, temperature wind direction and wind speed information for each sounding level from the upper air data file. However, due to the unavailability of upper air data in the format required for READ56, modifications were made to the READ56 program and additional preprocessing programs developed in order to accept the available meteorological data format. Appendix 2 details the changes to the MESOPUFF II modelling system including the preprocessing modifications and additions made.

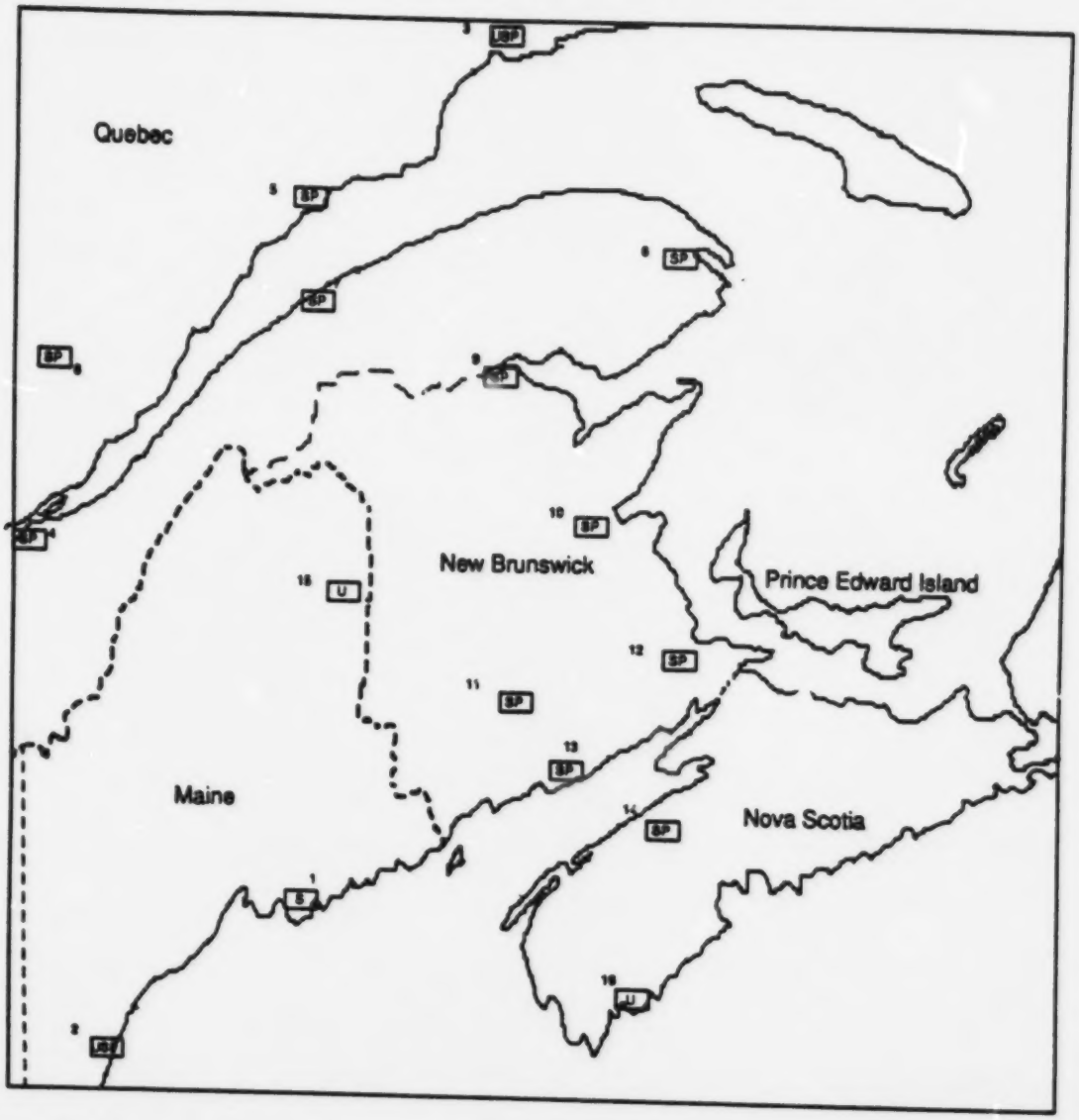
TABLE 3-1

Stations For Providing Meteorological Data

CATEGORY OF DATA	U.S. STATIONS	CANADIAN STATIONS
Upper Air	Portland, Maine Caribou, Maine	Sept-Iles, Que. Shelburne, N.S.
Surface	Portland, Maine Bangor, Maine	Quebec City, Que. Baie-Comeau A., Que. Sept-Isles, Que. Gaspe, Que. Mont Joli, Que. Bagotville, A., Que. Charlo, N.B. Chatham, N.B. Fredericton, N.B. Moncton, N.B. Saint John, N.B. Greenwood, N.S.
Precipitation	Portland, Maine	Quebec City, Que. Baie-Comeau A., Que. Sept-Iles, Que. Gaspe, Que. Mont Joli, Que. Bagotville, A., Que. Charlo, N.B. Chatham, N.B. Fredericton, N.B. Moncton, N.B. Saint John, N.B. Greenwood, N.S.

FIGURE 3-3

Locations of the Meteorological Stations



The output file generated by READ56 had to be edited to ensure the completeness of data because the output file contained several warning messages and flags indicating invalid and missing data. Since no missing or flagged data are allowed in the MESOPAC II output file, the flags and warning messages must be eliminated. The schemes used to eliminate missing data were as follows. When the data fields for all or most of the levels had been flagged, the whole record of that sounding was replaced by the record of the corresponding sounding of the previous day. Note that upper air soundings are taken twice daily thus the previous day's sounding is more appropriate than the previous or successive (12 hours earlier or later) sounding. On the other hand, if a few levels of the field(s) had been flagged, the missing values were estimated by reference to those of upper and lower levels of that sounding. Once all data were in order, the MESOPAC II model was used to extract and compute the required meteorological fields into a single file which served as the input to the MESOPUFF II dispersion model.

The parameters from the hourly surface meteorological data file required by the MESOPUFF II model are cloud cover, ceiling height, precipitation type, wind speed, wind direction, surface pressure, temperature and relative humidity.

3.3.3 Source and Emissions Data

MESOPUFF II models emissions from both point and area sources. Point source emissions are modelled using pollutant emission rates, stack height, stack diameter, stack gas exit velocity and stack gas temperature. Area source emissions are modelled using pollutant emission rates together with the effective area source height and initial horizontal and vertical dispersion coefficients.

Major SO_2 emission sources in the computational grid are located in New Brunswick, Nova Scotia, Quebec and Eastern Maine. The emission information in these areas was obtained from several sources including Environment Canada, New Brunswick Power, New Brunswick Department of the Environment, Nova

Scotia Power, and the Department of Environmental Protection in Maine. A total of 107 stacks were identified as significant emission sources to be modelled. Emissions from smaller sources other than the identified stacks were accounted for in the area sources. Area sources were defined for six cities in New Brunswick, namely, Bathurst, Campbellton, Edmundston, Fredericton, Moncton and Saint John.

The sources were divided according to their location into 4 groups for MESOPUFF II runs. Each source group contains from one to sixteen sources. The four source groups were, A, the Coleson Cove TGS alone; B, sources in southern New Brunswick; C, sources in northern New Brunswick and D, out of province sources. The groupings of the point and area sources are shown in Tables 3-2 and 3-3, respectively. Throughout the remainder of this report, the out of province source group terminology is used to identify sources within the model domain that were modelled. The term background (sources) refers to sources outside the model domain that contribute to background within the model domain. The natural sources within the model domain are assumed to be negligible compared to man-made sources outside the model domain.

3.3.3.1 Point Sources

Of the 107 stacks identified as point sources not all had complete stack parameter data. The missing stack parameters were estimated by reference to similar processes.

Although MESOPUFF II model was run for seasonal scenarios, most of the emission rates were available as annual rates except for NB Power and Irving Oil Refinery sources. All available seasonal emission rates were used. For the remaining sources, a constant emission rate throughout the year was assumed.

TABLE 3-2A

Stack Parameters of Combined Point Sources for MESOPUFF II Model Inputs

Stack No.	Source Name	Location	Source Group	Model Domain X-grid	Model Domain Y-grid	Stack Height H (m)	Stack Diameter D (m)	Exit Gas Velocity (m/s)	Exit Gas Temp (°K)
1	NB Power - Coleson Cove	NB	A	19.98	11.21	183.0	4.90	30.5	423
2-3	FlakeBoard	NB	B	15.73	11.37	14.2	0.56	10.0	475
4	Irving Pulp and Paper	NB	B	20.44	11.83	90.0	4.40	13.2	458
5-6	Irving Refinery - St. John	NB	B	20.66	11.95	73.0	2.70	7.7	505
7-11	Irving Refinery - St. John	NB	B	20.66	11.95	32.8	1.74	13.1	793
12-13	Irving Refinery - St. John	NB	B	20.66	11.95	60.0	0.90	15.0	644
14	Lantic Sugar	NB	B	20.60	11.86	48.0	2.70	0.7	523
15-18	Miramichi Pulp & Paper Ind.	NB	B	21.99	21.28	46.1	2.35	11.7	461
19	NB Power - Chatham	NB	B	22.49	21.63	76.0	3.00	7.0	443
20	NB Power - Courtenay Bay	NB	B	20.75	11.88	107.0	3.70	12.5	423
21	NB Power - Grand Lake	NB	B	20.59	16.33	76.0	3.80	9.0	463
22	Rothesay Paper	NB	B	20.14	12.50	50.3	2.70	10.0	563
23	Saint John Regional Hospital	NB	B	20.48	12.09	64.0	0.40	1.4	473
24	Utopia - pulp mill	NB	B	17.90	11.05	12.9	2.50	10.0	400
25-26	Atholville Pulp	NB	C	17.54	26.93	44.5	0.25	8.7	329
27	Atholville Pulp	NB	C	17.54	26.93	34.2	0.61	28.8	315
28	Atholville Pulp	NB	C	17.54	26.93	65.2	1.37	7.9	347
29	BMS Smelter	NB	C	21.07	26.48	68.6	2.29	11.2	343
30	BMS Smelter	NB	C	21.07	26.48	39.6	3.05	21.6	328
31	BMS Smelter	NB	C	21.07	26.48	39.6	3.96	17.7	333
32	Consolidated Bathurst (pulp mill)	NB	C	21.69	24.80	33.0	0.20	10.0	400
33-36	Fraser Inc., Edmundston	NB	C	11.57	23.35	43.7	2.03	12.0	394
37	NB Power - Dalhousie	NB	C	18.92	27.30	84.0	3.00	18.5	433
38	NB Power - Dalhousie	NB	C	18.92	27.30	168.0	3.90	24.0	444
39	NBIP	NB	C	18.82	27.39	38.1	2.59	9.2	408
40	St. Anne-Nackawic Pulp Co. Ltd.	NB	C	15.89	15.91	52.1	3.96	13.6	422
41-42	Eastern fine paper	ME	D	9.90	8.95	46.0	3.05	11.3	450
43-50	Facilities in Limestone, Ft Fairfield	ME	D	13.26	20.95	48.0	1.32	12.4	491
51-58	Facilities in Lincoln	ME	D	10.97	12.24	37.0	1.50	14.3	471
59-66	Great Northern Paper	ME	D	10.21	13.78	89.0	4.45	15.4	432
67-74	James River Corp	ME	D	10.49	9.73	41.0	2.18	12.9	433
75-80	Facilities in Woodland	ME	D	15.55	11.15	76.0	2.60	0.3	390
81	NS Power - Maccan GS	NS	D	27.47	14.23	38.0	2.83	30.5	455
82	NS Power - Point Tupper GS	NS	D	38.87	13.68	107.0	3.35	30.5	422
83	NS Power - Trenton GS	NS	D	33.90	13.57	91.4	3.20	30.5	419
84-86	NS Power - Tufts Cove GS	NS	D	30.47	8.40	152.0	3.05	30.5	432
87-92	Texaco Canada Inc	NS	D	30.86	8.11	39.0	0.93	10.7	771
93-96	Consol-Barthust, Dev Chaleurs	QUE	D	20.82	27.97	39.8	1.89	10.0	383
97-98	F.F. Soucy Inc	QUE	D	7.18	25.93	38.0	1.68	10.0	456
99-102	La Compagnie Gaspesia Ltee	QUE	D	25.06	28.87	52.5	2.97	10.0	480
103-107	Soc Canadienne De Metaux Reynolds Lt	QUE	D	12.14	33.83	58.2	3.55	10.0	356

TABLE 3-2B

SO_2 Emission Rates for Combined Point Sources for MESOPUFF II Model Inputs

Stack No.	Source Name	Seasonal SO2 Emission Rate (g/s)							
		season 1	season 2	season 3	season 4	season 5	season 6	season 7	season 8
1	NB Power - Coleson Cove	1314.6	1944.5	3048.5	2074.9	1953.6	2354.1	3181.3	2295.0
2-3	FlakeBoard	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
4	Irving Pulp and Paper	81.2	81.2	81.2	81.2	81.2	81.2	81.2	81.2
5-6	Irving Refinery - Saint John	12.6	12.5	9.9	8.8	10.2	9.2	15.7	8.8
7-11	Irving Refinery - Saint John	14.5	61.6	93.3	20.3	35.4	85.5	122.2	109.7
12-13	Irving Refinery - Saint John	97.2	109.5	101.7	46.9	72.6	99.6	91.5	101.3
14	Lantic Sugar	28.5	28.5	28.5	28.5	28.5	28.5	28.5	28.5
15-18	Miramichi Pulp & Paper Ind.	39.1	39.1	52.7	59.9	59.9	59.9	90.2	106.1
19	NB Power - Chatham	20.5	12.9	39.9	13.8	0.2	12.2	16.3	4.6
20	NB Power - Courtenay Bay	177.6	269.4	649.4	405.1	144.0	504.9	781.1	582.9
21	NB Power - Grand Lake	946.6	386.8	1070.4	508.7	889.8	1046.5	1131.5	565.2
22	Rothesay Paper	14.3	14.3	14.3	14.3	14.3	14.3	14.3	14.3
23	Saint John Regional Hospital	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
24	Utopia - pulp mill	44.6	44.6	44.6	44.6	44.6	44.6	44.6	44.6
25-26	Atholville Pulp	271.9	271.9	271.9	271.9	271.9	271.9	271.9	271.9
27	Atholville Pulp	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1
28	Atholville Pulp	52.4	52.4	52.4	52.4	52.4	52.4	52.4	52.4
29	BMS Smelter	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
30	BMS Smelter	102.3	102.3	150.2	175.3	175.3	175.3	175.3	175.3
31	BMS Smelter	186.3	186.3	144.2	122.1	122.1	122.1	122.1	122.1
32	Consolidated Bathurst (pulp mill)	16.8	16.8	16.8	16.8	16.8	16.8	16.8	16.8
33-36	Fraser Inc., Edmundston	96.1	96.1	96.1	96.1	96.1	96.1	96.1	96.1
37	NB Power - Dalhousie	70.9	251.5	288.2	250.8	226.1	238.4	338.9	184.7
38	NB Power - Dalhousie	1165.7	1720.3	2398.3	1100.3	1310.0	1856.7	2186.6	1139.5
39	NBIP	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0
40	St. Anne-Nackawic Pulp Co. Ltd.	104.0	104.0	104.0	104.0	104.0	104.0	104.0	104.0
41-42	Eastern fine paper	40.4	40.4	40.4	40.4	40.4	40.4	40.4	40.4
43-50	Facilities in Limestone, Ft Fairfield	23.7	23.7	23.7	23.7	23.7	23.7	23.7	23.7
51-58	Facilities in Lincoln	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0
59-66	Great Northern Paper	305.0	305.0	305.0	305.0	305.0	305.0	305.0	305.0
67-74	James River Corp	118.1	118.1	118.1	118.1	118.1	118.1	118.1	118.1
75-80	Facilities in Woodland	59.4	59.4	59.4	59.4	59.4	59.4	59.4	59.4
81	NS Power - Maccan GS	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8
82	NS Power - Point Tupper GS	672.3	672.3	672.3	672.3	672.3	672.3	672.3	672.3
83	NS Power - Trenton GS	431.3	431.3	431.3	431.3	431.3	431.3	431.3	431.3
84-86	NS Power - Tufts Cove GS	665.9	665.9	665.9	665.9	665.9	665.9	665.9	665.9
87-92	Texaco Canada Inc	178.1	178.1	178.1	178.1	178.1	178.1	178.1	178.1
93-96	Consol-Barthust, Dev Chaleurs	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7
97-98	F.F. Soucy Inc	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
99-102	La Compagnie Gaspesia Ltee	28.6	28.6	28.6	28.6	28.6	28.6	28.6	28.6
103-107	Soc Canadienne De Metaux Reynolds Lt	122.3	122.3	122.3	122.3	122.3	122.3	122.3	122.3
Seasonal Totals: New Brunswick (t/season)		39684	47165	70423	44722	46396	58735	72048	49518
Annual Totals: New Brunswick (t/y)		5033			201993				226696
Seasonal Total: NB Power Sources (t/season)		29138	36151	59088	34323	35665	47404	60200	37621
Annual Totals: NB Power (t/y)					158701				180891
Annual Totals: Sources other than NB Power (t/y)					43292				45805

TABLE 3-3

Area Sources for MESOPUFF

CITY	CORRESPONDING COUNTY	SOURCE GROUP (1)	MODEL DOMAIN		EFFECTIVE HEIGHT (m)	σ_y (m)	σ_z (m)	EMISSION RATES
			X-GRID	Y-GRID				SO_2 (g/s)
Fredericton	York	B	18.20	15.60	5	2987	10	8.32
Moncton	Westmoreland	B	26.00	17.00	5	3117	10	12.17
Saint John	Saint John	B	20.50	12.00	5	4715	10	16.07
Bathurst	Gloucester	C	21.50	24.50	5	2502	10	5.67
Campbellton	Restigouche	C	18.50	27.00	5	1091	10	5.44
Edmunston	Madawaska	C	12.00	24.00	5	1543	10	11.94

(1) Sources are grouped by MESOPUFF runs according to their locations. The locations for those groups are:

B - New Brunswick South
C - New Brunswick North

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The locations, stack parameters and the emission rates of the individual stacks are listed in Appendix 3. Due to the limitation of the number of sources that could be included in each run, some of the stacks were combined for the modelling. In the case of sources within New Brunswick, some of the stacks from the same plant were combined. For out of province (more distant) sources, some stacks from different facilities, which are within 5 km of each other, were combined. As a result, the number of point sources was reduced to 41 stacks. The locations of the point sources inside and outside New Brunswick are shown on Figures 3-4 and 3-5, respectively.

Stack parameters for the combination of sources were calculated as follows. For the combined stack, the effective stack diameter, effective stack gas exit velocity and effective stack gas temperature was calculated by weighting the individual stack parameters by their final plume rise. The relationship of plume rise Δh, with stack parameters has been assumed to be (Briggs, 1975):

$$\Delta h \propto \frac{W_l}{U} D_l \left(\frac{T_l - T_a}{T_a} \right) \qquad [3\text{-}1]$$

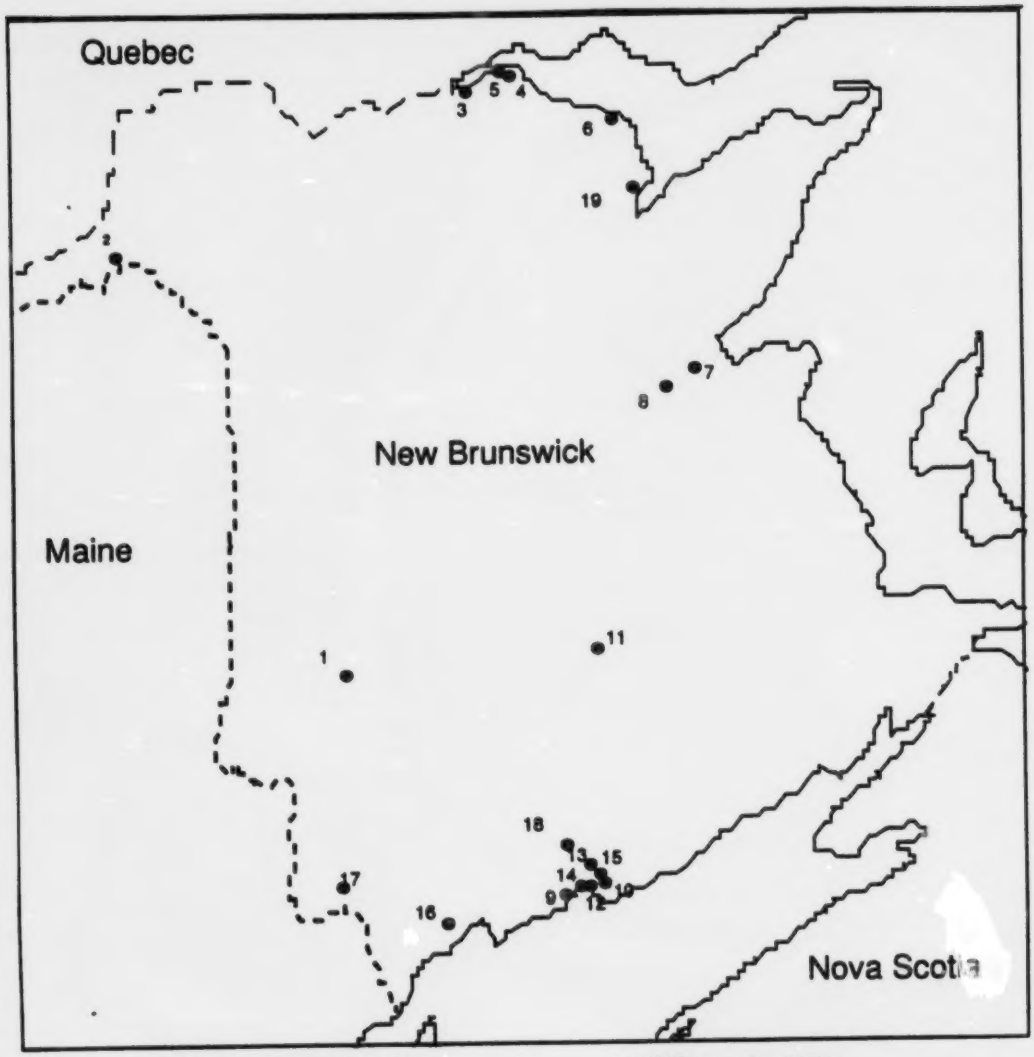
where:

W_l = stack gas exit velocity
U = wind velocity
D_l = stack diameter
T_l = absolute stack gas temperature
T_a = ambient air temperature

Since U and T_a will be constant for each stack and that $T_l > T_a$, plume rise is proportional to $W_l D_l T_l$ as a rough approximation.

FIGURE 3-4

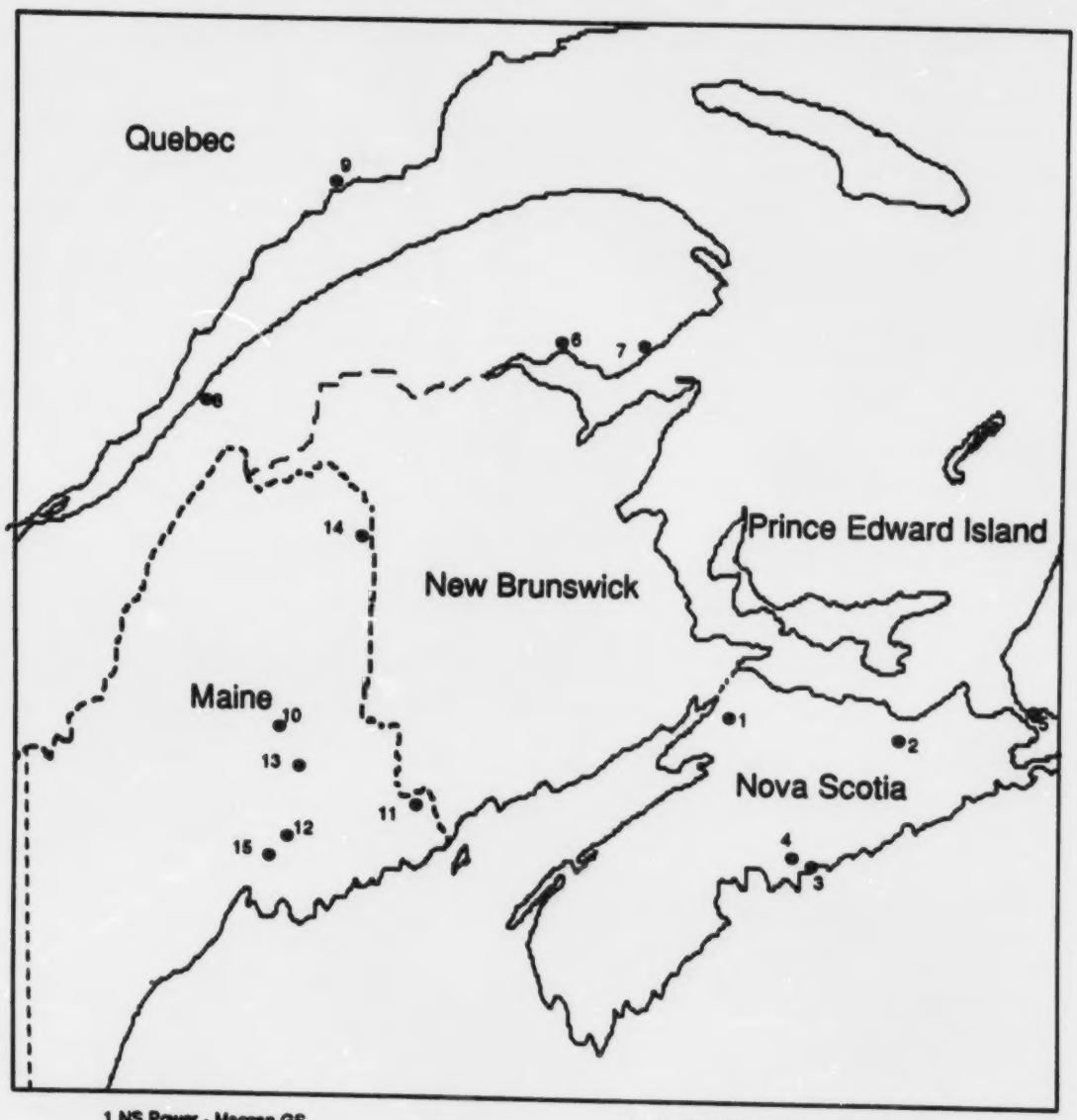
Locations of Point Sources in New Brunswick



1 St Anne-Nackawic Pulp Co Ltd
2 Fraser Inc, Edmundston
3 Atholville Pulp
4 NB Power - Dalhousie
5 New Brunswick International Paper Co
6 Brunswick Mining & Smelting Co
7 NB Power - Chatham
8 Miramichi Pulp & Paper Ind
9 NB Power - Coleson Cove
10 NB Power - Courtenay Bay
11 NB Power - Grand Lake
12 Lantic Sugar
13 St John Regional Hospital
14 Irving Pulp and Paper
15 Irving Oil Refinery
16 Utopia Pulp Mill
17 Flakeboard Co Ltd
18 Rothesay Paper
19 Consolidated Bathurst

FIGURE 3-5

Locations of Point Sources Outside New Brunswick



1 NS Power - Maccan GS
2 NS Power - Trenton
3 Texaco Canada Inc
4 NS Power - Tufts Cove GS
5 NS Power - Point Tupper GS
6 Consol-Bathurst, Div Chaleurs
7 La Compagnie Gaspesia Ltee
8 F.F. Soucy Inc
9 Societe Canadienne De Metaux Reynolds Lt
10 Great Northern Paper
11 Georgia-Pacific Corp, and
OSB & Chip-N-Saw
12 James River Corp
13 Lincoln Pulp & Paper Co,
Beaver Wood Joint Venture, and
Penobscot Valley Hospital
14 Loring Air Force Base,
Fairfield Energy Venture, and
Interstate Food Processing Corp
15 Eastern Fine Paper Inc

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The weighting factor for the ith stack when combining n stacks is given by:

$$Wt_i = \frac{D_i T_i W_i}{\sum_{i=1}^{N} D_i T_i W_i} \qquad [3\text{-}2]$$

Therefore, the effective stack parameters are given by:

$$W_{eff} = \sum_{i=1}^{N} Wt_i W_i$$

$$D_{eff} = \sum_{i=1}^{N} Wt_i D_i \qquad [3\text{-}3]$$

$$T_{eff} = \sum_{i=1}^{N} Wt_i T_i$$

where:

W_{eff} = effective gas exit velocity of the combined stacks

D_{eff} = effective stack diameter of the combined stacks

T_{eff} = effective stack gas temperature of the combined stacks

The resultant stack height representing the combined sources was taken as the average of the effective stack heights of the stacks to be combined. The location of the combined stacks in Maine from different facilities was taken as the location of the stack which has the highest SO_2 emissions. The location, stack parameters and emission rates of the combined point sources for input to MESOPUFF II are listed in Table 3-2.

3.3.3.2 Area Sources

Several smaller SO_2 sources not included in the 107 sources are located primarily in major urban centres. There are six census subdivisions classified as cities in New Brunswick namely Bathurst, Campbellton, Edmundston, Fredericton, Moncton and Saint John. Small SO_2 sources in these counties, which had not been taken

into account as point sources were grouped together into area sources and modelled as if they were from these six cities.

The location, effective source height, dispersion coefficients and emission rates for the six area sources are shown in Table 3-3.

3.3.4 Land Use Data

The characterization of the predominant land use in each grid square is required as input to the model. MESOPUFF II model uses the land use categories of Sheih et al. (1979) shown in Table 3-4. There are altogether 12 categories. Although land use information from satellite imagery is becoming available, the methodology for translating the images into the land use categories required by the model is not yet fully developed. Therefore, in this study topographic maps were used to establish the land use type for each grid square in the modelling domain. The land use category associated with each grid square is shown in Figure 3-6. The land uses in the modelling domain fall into the following 7 categories:

Category	Land Use Type
1	cropland and pasture
2	cropland, woodland and grazing land
4	grazed forest and woodland
5	ungrazed forest and woodland
9	swamp
11	metropolitan city
12	lake or ocean

On the whole, the land use in the modelling domain is mostly ungrazed forest/woodland or lake/ocean (see Figure 3-6).

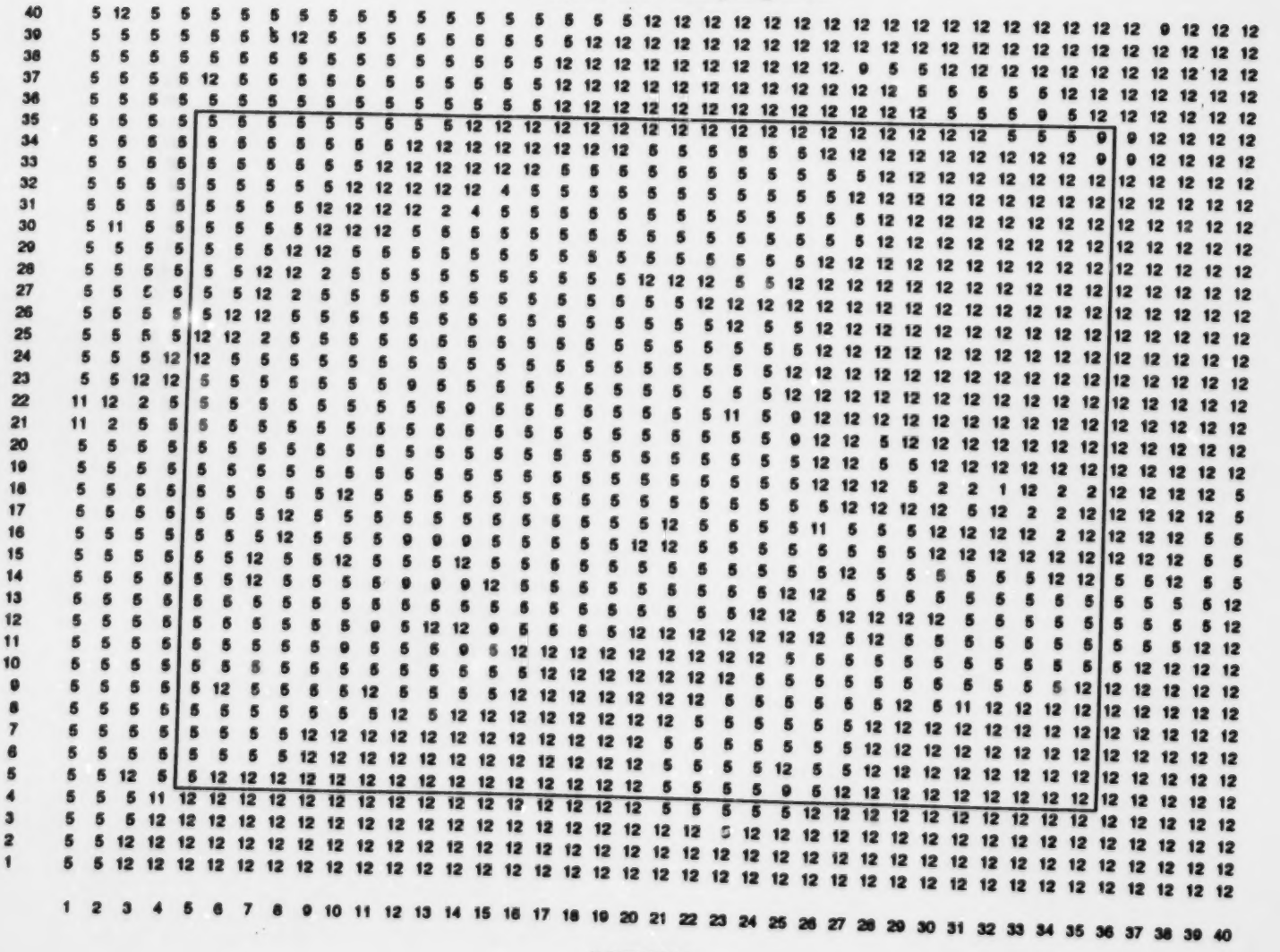
Table 3-4

Land Use Categories in MESOPUFF II Model

Category	Land Use Type
1	cropland and pasture
2	cropland, woodland and grazing land
3	irrigated crops
4	grazed forest and woodland
5	ungrazed forest and woodland
6	subhumid grassland and semi-arid grazing land
7	open woodland grazed
8	desert shrubland
9	swamp
10	marshland
11	metropolitan city
12	lake or ocean

FIGURE 3-6

Land Use Category for Each Grid Point
Outer Grid: Meteorological and Computational Grid
Inner Grid: Sampling Grid



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3.3.5 Model Input Parameters

The input control parameters to MESOPUFF II include the computational variables and the parameters for the overridden default options. The computational variables control the computation interactions in the model. The MESOPUFF II model was set to simulate one puff generated per hour by each source and to calculate the average concentration in the puff every hour. The sampling rate at the receptors was set to vary with the wind speed. The minimum sampling rate was 2 samples/hour and reference wind speed in the sampling equation was 2 m/s. The minimum age of puffs to be sampled was 900 s (0.25 hours).

A sample output listing of MESOPUFF II showing the technical options used in the simulations is contained in Appendix 4. The default values of the major technical options were selected, with the exception of the parameter TMDEP. This parameter controls the distance at which the time-dependent equations are used to compute the dispersion coefficients, σ_x and σ_y. A value of 10 km was selected for TMDEP instead of the default 100 km because recent model results have shown a tendency for the distance-dependent equations to under predict plume width (Scire et al., 1990). As the time-dependent puff growth equations given by Hefter (1965) yield generally larger dispersion coefficients, the plume dimensions and concentrations are more accurately predicted with the smaller value of TMDEP.

Since the SO_2 canopy resistance is specified in MESOPUFF II as a function of land use and atmospheric stability, in order to introduce the seasonal dependency of SO_2 canopy resistance, MESOPAC II and MESOPUFF II were run in eight seasons. The seasons were defined as (1,5) winter: December-February; (2,6) spring: March-May; (3,7) summer: June-August; and (4,8) fall: September-November. The appropriate seasonal values for the SO_2 canopy resistance were entered for each run. These values are presented in Table 3-5.

TABLE 3-5

SO_2 Canopy Resistance (r_c) as a Function of Land Use Category, Stability Class, and Season (s/cm)

LAND USE CATEGORY	DESCRIPTION	WINTER				SPRING				SUMMER				FALL			
		A,B,C	B	E	F	A,B,C	B	E	F	A,B,C	B	E	F	A,B,C	B	E	F
1	Cropland & pasture	300	500	2000	2000	200	300	500	100	100	300	1000	80	200	300	500	100
2	Cropland, woodland & grazing land	500	500	2000	2000	300	400	500	100	100	300	1000	50	300	400	500	100
3	Irrigated crops	300	300	1000	1000	200	300	400	100	100	300	500	80	200	300	400	100
4	Forest & woodland grazed	700	700	2000	2000	500	500	1200	100	100	300	1000	50	500	500	1200	100
5	Forest & woodland ungrazed	500	500	2000	2000	200	400	1000	100	50	150	500	10	200	400	1000	100
6	Subhumid grassland & semiarid grazing land	500	1000	1500	1500	400	500	1000	300	200	500	1250	100	400	500	1000	300
7	Open woodland grazed	500	500	1000	1000	300	400	500	200	100	300	1000	50	300	400	500	200
8	Desert shrubland	1000	1000	5000	5000	700	800	2000	1500	500	750	1500	500	700	800	2000	1500
9	Swamp	400	400	1000	1000	200	100	300	100	50	80	100	10	200	100	300	100
10	Marshland	400	400	1000	1000	200	300	600	200	80	200	400	20	200	300	600	200
11	Metropolitan City	300	300	1000	1000	500	500	1000	700	500	750	1500	500	500	500	1000	700
12	Lake or ocean	5	5	5	2	5	5	5	2	5	5	5	2	5	5	5	2

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4 RESULTS AND DISCUSSION

4.1 OVERVIEW

The model validation strategy that was envisaged called for model predictions for the first year of data and adjustment of model parameters (within reason) in order to obtain the "best available" comparison with the observed wet deposition measurements. Once model parameters were established, then model runs would be performed for the second year without further adjustment and again comparing the predicted and observed wet deposition.

The sensitivity tests performed indicated that the surface resistance for SO_2 was the parameter that presented the best opportunity for consistent adjustment of model predictions. Sensitivity runs were made for three levels of the SO_2 canopy resistance for three seasons. The levels used were the default values (base case or 100%) and 50% and 200% of the base case. Three rather than four seasons and two of the four source groups were used for the 50% and 200% levels for the SO_2 canopy resistance since the values of the canopy resistance for spring and fall were assumed to be identical.

Adjustments to the predicted wet sulphur deposition were made to account for the difference between the precipitation measured at the receptor and the model input precipitation. The predicted wet deposition is a function of the precipitation amount as well as the ambient concentrations of sulphur species that are washed out or scavenged by the precipitation. The amount washed out is actually an exponential function of the precipitation rate and the concentration (see equation 2-17). As a first approximation, we have assumed that the amounts washed out by two different precipitation amounts (for the same concentration being scavenged) is directly proportional rather than exponentially related to the precipitation rate. The adjusted wet deposition P_{adj} at each receptor i, is given by the following equation:

$$P_{adj} = P_i \left(\frac{P_{obs_i}}{P_{m_i}} \right) \qquad [4\text{-}1]$$

where P_{obs_i} and P_{m_i} are respectively the precipitation measured at the receptor wet deposition monitoring site) and the precipitation at the hourly meteorological station that is nearest to the receptor. It should be noted that this adjustment is made for weekly (or longer) periods outside of the model. This adjustment compensates for the sparsity of meteorological stations with hourly precipitation observations and the need for the model to rely on hourly precipitation data from the site nearest to the receptor.

Comparison of seasonal model predictions with observations indicated that the predicted wet deposition levels were small fractions (7 to 25%) of the observations. This is a consequence of the high background level caused by long range transport into the model domain. This is consistent with back trajectory data (Davis, 1991) and with previous modelling studies (U.S. EPA, 1987) involving the entire eastern North American domain in which model predictions were much larger fractions of observations due to the inclusion of most of the sources in the model domain. Because of the high background in the present situation, customary methods used to establish performance statistics were unsuitable. The statistics used to determine model performance include comparison of the difference between observations and predictions and assessing the correlation or association between observations and predictions in various ways, e.g., over time and or space. Estimation of the background wet deposition is necessary and provides the most challenging aspect of the study.

Background air concentrations and thus deposition are expected to vary spatially (i.e., a spatial gradient in the SO_2 concentration field caused by long range transport is expected). In addition, the spatially varying precipitation amount is expected to influence the background wet deposition. As indicated previously, two methods were considered for estimating the background wet deposition.

Model predictions on the scale of Eastern North America were considered but the spatial resolution is coarse (127 km by 127 km grids) hence the spatial gradient over the model domain is expected to be small. Furthermore, since wet deposition is very dependent on the precipitation amount, long term (e.g., seasonal) estimates of wet deposition would be needed - such as would be available from the SERTAD model. Such model predictions were not readily undertaken since current emission inventory and meteorological data would be needed. Use of climatological meteorological data would not be inappropriate but current emissions inventory would be needed. The available emissions inventory data that could be readily used by SERTAD are for 1980 but not for 1985 which are the most recent. Furthermore, estimates of the background wet deposition over one week periods would be needed for more detailed model validation. Such estimates cannot reliably be provided by a statistical model. In view of these factors, use of SERTAD model predictions to estimate background wet deposition was not pursued.

The second method requires an empirical estimation of the background based on the mean of the difference between observed and predicted wet deposition levels with or without incorporation of some scheme to account for a background that is dependent on the amount of precipitation. One approach was to use some relationship involving the mean of the difference between the observed and predicted deposition as the background. The scheme adopted was to define the station-specific background, (B_{adj}), as the mean of the difference between observed (O) and adjusted predicted (P_{adj}) wet deposition for all stations and multiplied by the ratio of the observed precipitation at each wet deposition monitoring station $(P_{obs})_i$ to the mean observed precipitation ($\overline{P}_{obs}$) at each hourly meteorological station as follows:

$$B_{adj_i} = \overline{O_i - P_{adj_i}} \left[\frac{(P_{obs})_i}{\overline{P}_{obs}} \right] \qquad [4\text{-}2]$$

where O_i is the seasonal or weekly observed wet deposition amount at receptor i and $(P_{obs})_i$ are the corresponding predicted amount. MESOPUFF model predictions are initially provided as hourly estimates of wet and dry deposition and air concentrations for SO_2 and $SO_4^=$. Wet deposition for the sulphur species were summed to obtain weekly or seasonal amounts by first converting each to the wet sulphur equivalent and then adding the sulphur deposition amounts. Model predictions were adjusted by the ratio of the measured precipitation amount to the model input precipitation amount as derived from the hourly precipitation meteorological data.

The observed wet deposition O_i was the seasonal or weekly sea-salt-corrected wet sulphate deposition taken from the database of wet deposition measurements (Davis, 1991). The sea-salt correction eliminates the contribution of sulphate in sea spray which can affect wet deposition at sites typically within 20 km of the sea. The observations were corrected to account for those precipitation events which had precipitation but for which no chemistry data (measurements of deposition) were available. The correction applied was the reported deposition multiplied by the ratio of the total precipitation (standard rain gauge) at the station divided by the rain gauge measurements associated with deposition (chemical analyses) measurements.

4.2 SENSITIVITY RUNS

Sensitivity runs for the three seasons are summarized in Tables 4-1 to 4-3. Measurements at each receptor and model predictions for the three levels 50%, 100% and 200% of the base case canopy resistance, RCSO2, without and with background corrections are listed for each season. Also listed in Tables 4-1 to 4-3

TABLE 4-1

SUMMARY OF SENSITIVITY TESTS ON SO2 CANOPY RESISTANCE (RCSO2) FOR SEASON 1, SUMMER 88

RECEPTOR	OBSERVED S DEP (1) (kg/ha)	PREDICTED WET S DEP (kg/ha)					
		MODEL PREDICTION (2)			TOTAL WITH ADJUSTED BACKGROUND (3)		
		50% BASE	100% BASE	200% BASE	50% BASE	100% BASE	200% BASE
3	1.76	0.055	0.097	0.085	1.836	1.839	1.834
4	2.47	0.090	0.129	0.121	2.102	2.097	2.096
6	2.56	0.098	0.147	0.136	2.041	2.048	2.043
7	2.27	0.178	0.249	0.241	2.154	2.182	2.181
8	2.70	0.113	0.197	0.168	1.966	2.009	1.986
9	1.99	0.068	0.108	0.099	2.092	2.087	2.086
12	2.64	0.596	0.634	0.638	2.651	2.644	2.655
13	2.39	0.225	0.241	0.239	2.234	2.207	2.212
14	1.64	0.225	0.251	0.250	2.004	1.992	1.996
15	2.59	0.239	0.296	0.289	2.372	2.384	2.384
16	2.35	0.191	0.214	0.214	2.384	2.361	2.367
17	1.92	0.251	0.308	0.303	2.272	2.285	2.287
18	2.36	0.172	0.206	0.206	1.861	1.859	1.864
19	2.18	0.354	0.409	0.406	2.368	2.380	2.383
20	2.27	0.214	0.264	0.257	2.071	2.082	2.081
21	2.80	0.428	0.478	0.473	2.851	2.849	2.852
23	2.34	0.432	0.461	0.461	2.886	2.862	2.871
24	1.10	0.064	0.110	0.098	2.085	2.088	2.082
26	1.82	0.039	0.077	0.063	1.500	1.507	1.498
30	1.80	0.026	0.041	0.036	2.207	2.175	2.177
AVERAGE: ALL RECEPTORS	2.20	0.20	0.25	0.24	2.20	2.20	2.20
AVERAGE: CC/SJ RECEPTORS	2.32	0.30	0.34	0.34	2.36	2.35	2.36
Regression for all receptors							
Constant		1.92	1.85	1.87	0.97	0.90	0.93
Std Err of Y Est		0.40	0.38	0.38	0.39	0.39	0.39
R Squared		0.15	0.26	0.25	0.19	0.21	0.20
No. of Observations		20	20	20	20	20	20
Degrees of Freedom		18	18	18	18	18	18
X Coefficient(s)		0.89	1.41	1.35	0.56	0.59	0.58
Std Err of Coef.		0.50	0.57	0.56	0.27	0.27	0.27
Regression for CC/SJ receptors only							
Constant		2.30	1.94	1.95	1.00	0.99	0.99
Std Err of Y Est		0.34	0.30	0.31	0.28	0.28	0.28
R Squared		0.00	0.21	0.20	0.32	0.32	0.32
No. of Observations		11	11	11	11	11	11
Degrees of Freedom		9	9	9	9	9	9
X Coefficient(s)		0.04	1.09	1.07	0.56	0.56	0.56
Std Err of Coef.		0.39	0.71	0.70	0.27	0.27	0.27

(1) Reported S deposition measurement adjusted by the ratio of total precipitation measured and the precipitation associated with sulphur deposition.

(2) Estimation based on predictions for Coleson Cove and New Brunswick South for 50%, 100% and 200% of RCSO2. Predictions for New Brunswick North and out-of-province source groups are for the base case 100%.

(3) Adjusted background = background x (observed precip/mean observed precip at wet deposition stations) where background = average(observed S dep - predicted S dep)

TABLE 4-2

SUMMARY OF SE TIVITY TESTS ON SO2 CANOPY RESISTANCE (RCSO2) FOR SEASON 2, FALL 88

RECEPTOR	OBSERVED S DEP (1) (kg/ha)	PREDICTED WET S DEP (kg/ha)					
		MODEL PREDICTION (2)			TOTAL WITH ADJUSTED BACKGROUND (3)		
		50% BASE	100% BASE	200% BASE	50% BASE	100% BASE	200% BASE
3	0.89	0.035	0.050	0.045	0.622	0.581	0.626
4	0.60	0.206	0.241	0.231	1.056	1.010	1.071
6	0.77	0.106	0.211	0.116	0.832	0.868	0.835
7	0.95	0.092	0.071	0.102	0.864	0.770	0.867
8	1.24	0.072	0.098	0.089	0.814	0.770	0.823
9	0.98	0.079	0.089	0.091	0.847	0.784	0.850
12	1.24	0.380	0.612	0.383	1.352	1.492	1.345
13	1.41	0.464	0.798	0.466	1.529	1.762	1.520
14	0.82	0.231	0.277	0.237	0.817	0.808	0.818
15	0.84	0.139	0.250	0.146	0.911	0.949	0.910
16	1.44	0.069	0.114	0.071	1.120	1.066	1.112
17	0.97	0.282	0.540	0.297	1.175	1.348	1.180
18	0.85	0.086	0.137	0.091	0.697	0.691	0.696
19	0.86	0.199	0.305	0.206	0.968	1.001	0.967
20	0.78	0.207	0.349	0.219	0.999	1.066	1.003
21	1.25	0.086	0.053	0.091	1.058	0.933	1.053
23	1.36	0.594	0.603	0.598	1.646	1.555	1.639
24	0.65	0.076	0.141	0.087	0.922	0.907	0.924
26	1.17	0.034	0.056	0.040	0.574	0.545	0.574
30	0.92	0.020	0.029	0.022	1.201	1.099	1.191
AVERAGE: ALL RECEPTORS	1.00	0.17	0.25	0.18	1.00	1.00	1.00
AVERAGE: CC/SJ RECEPTORS	1.07	0.25	0.37	0.26	1.12	1.15	1.11
Regression for all receptors							
Constant		0.90	0.91	0.90	0.56	0.65	0.56
Std Err of Y Est		0.24	0.25	0.24	0.23	0.23	0.23
R Squared		0.13	0.10	0.12	0.24	0.20	0.23
No. of Observations		20	20	20	20	20	20
Degrees of Freedom		18	18	18	18	18	18
X Coefficient(s)		0.59	0.36	0.57	0.44	0.35	0.44
Std Err of Coef.		0.36	0.25	0.36	0.19	0.17	0.19
Regression for CC/SJ receptors only							
Constant		0.91	0.94	0.91	0.29	0.49	0.30
Std Err of Y Est		0.25	0.26	0.25	0.18	0.21	0.18
R Squared		0.17	0.11	0.16	0.60	0.43	0.59
No. of Observations		11	11	11	11	11	11
Degrees of Freedom		9	9	9	9	9	9
X Coefficient(s)		0.65	0.37	0.63	0.70	0.51	0.70
Std Err of Coef.		0.47	0.35	0.48	0.19	0.20	0.19

(1) Reported S deposition measurement adjusted by the ratio of total precipitation measured and the precipitation associated with sulphur deposition.

(2) Estimation based on predictions for Coleson Cove and New Brunswick South for 50%, 100% and 200% of RCSO2. Predictions for New Brunswick North and out-of-province source groups are for the base case 100%.

(3) Adjusted background = background x (observed precip/mean observed precip at wet deposition stations) where background = average(observed S dep - predicted S dep)

TABLE 4-3

SUMMARY OF SENSITIVITY TESTS ON SO2 CANOPY RESISTANCE (RCSO2) FOR SEASON 3, WINTER 88/89

RECEPTOR	OBSERVED S DEP (1) (kg/ha)	PREDICTED WET S DEP (kg/ha)					
		MODEL PREDICTION (2)			TOTAL WITH ADJUSTED BACKGROUND (3)		
		50% BASE	100% BASE	200% BASE	50% BASE	100% BASE	200% BASE
3	0.52	0.006	0.012	0.006	0.627	0.623	0.623
4	0.52	0.028	0.037	0.028	0.769	0.766	0.763
6	0.58	0.008	0.017	0.012	0.559	0.558	0.558
7	0.54	0.016	0.032	0.023	0.792	0.796	0.793
8	0.49	0.008	0.013	0.007	0.660	0.654	0.654
9	0.44	0.013	0.022	0.013	0.684	0.681	0.679
12	1.34	0.008	0.049	0.046	0.957	0.962	0.967
13	1.73	0.009	0.019	0.016	1.340	1.328	1.337
14	1.24	0.192	0.229	0.224	1.189	1.209	1.213
15	0.81	0.032	0.053	0.033	0.803	0.810	0.798
16	1.20	0.018	0.023	0.021	0.943	0.932	0.939
17	0.96	0.040	0.069	0.046	1.078	1.090	1.076
18	1.01	0.130	0.179	0.172	0.950	0.985	0.986
19	0.97	0.029	0.048	0.034	0.852	0.858	0.851
20	0.73	0.018	0.034	0.022	0.794	0.798	0.792
21	1.08	0.010	0.022	0.019	0.891	0.888	0.892
23	1.43	0.227	0.188	0.182	1.300	1.242	1.246
27	1.11	0.189	0.207	0.204	0.958	0.963	0.967
24	0.59	0.006	0.019	0.014	0.850	0.849	0.852
30	1.04	0.012	0.020	0.013	1.344	1.329	1.334
AVERAGE: ALL RECEPTORS	0.92	0.05	0.06	0.06	0.92	0.92	0.92
AVERAGE: CC/SJ RECEPTORS	1.13	0.08	0.09	0.08	1.00	1.01	1.01
Regression for all receptors							
Constant		0.81	0.78	0.79	-0.28	-0.31	-0.30
Std Err of Y Est		0.34	0.34	0.33	0.21	0.20	0.20
R Squared		0.18	0.18	0.19	0.69	0.70	0.71
No. of Observations		20	20	20	20	20	20
Degrees of Freedom		18	18	18	18	18	18
X Coefficient(s)		2.15	2.15	2.20	1.30	1.33	1.33
Std Err of Coef.		1.08	1.08	1.06	0.20	0.21	0.20
Regression for CC/SJ receptors only							
Constant		1.09	1.10	1.09	-0.13	-0.19	-0.19
Std Err of Y Est		0.29	0.29	0.29	0.16	0.16	0.15
R Squared		0.03	0.01	0.02	0.70	0.69	0.71
No. of Observations		12	12	12	12	12	12
Degrees of Freedom		10	10	10	10	10	10
X Coefficient(s)		0.58	0.33	0.49	1.26	1.32	1.31
Std Err of Coef.		1.02	1.07	1.04	0.26	0.28	0.26

(1) Reported S deposition measurement adjusted by the ratio of total precipitation measured and the precipitation associated with sulphur deposition.

(2) Estimation based on predictions for Coleson Cove and New Brunswick South for 50%, 100% and 200% of RCSO2. Predictions for New Brunswick North and out-of-province source groups are for the base case 100%.

(3) Adjusted background = background x (observed precip/mean observed precip at wet deposition stations) where background = average(observed S dep - predicted S dep)

are the regression parameters (R^2, intercept, slope and the standard error of the slope). Plots of the % change in predicted wet deposition (without background) at selected receptors for each sensitivity test are shown in Figures 4-1 to 4-3. The patterns for the 3 seasons show consistent behaviour for most receptors. The base case values for the parameters that were varied yielded the highest model predictions for the majority of receptors. The exceptions to this behaviour are predictions for receptors 7, 9 and 21 in season 2 and receptor 23 in season 3. For season 1, there are relatively small changes of the model prediction (less than 15%) when $RCSO_2$ is doubled (see Table 4-1). When $RCSO_2$ is halved, the average relative change of the model prediction to the base case ranges from -6 to -50%. The larger percentage changes occurred as expected for the more distant (from Coleson Cove and the Saint John sources) receptors. For season 2, the average relative change is about -30% (see Table 4-2) when $RCSO_2$ is halved or doubled. For season 3, the percentage changes when $RCSO_2$ is halved are higher than for seasons 1 or 2 ranging from -9 to -90% (except for station 23 and are somewhat lower (-5 to -50%) when $RCSO_2$ is doubled.

These data suggest that the base case values for the canopy resistance are close to optimum values for $RCSO_2$. Since the background wet deposition was expected to be such a large component of the observed deposition, the determination of the background will have far greater influence on the combined model prediction than adjustments made by tuning of the model (e.g., changing values of $RCSO_2$). Thus, additional analysis of sensitivity runs to select better values for $RCSO_2$.

4.3 SUMMARY OF SEASONAL MODEL PREDICTIONS

4.3.1 Wet Sulphate Deposition

Model predictions for all 8 seasons are summarized in Appendix 5. Listings for each receptor are provided showing the observed rainfall; the model input rainfall;

FIGURE 4-1

MESOPUFF II SENSITIVITY MODEL RESULTS OF PREDICTED SEASONAL WET S DEPOSITION DUE TO THE COLESON COVE AND N.B. SOUTH SOURCES

SEASON 1, SUMMER 88

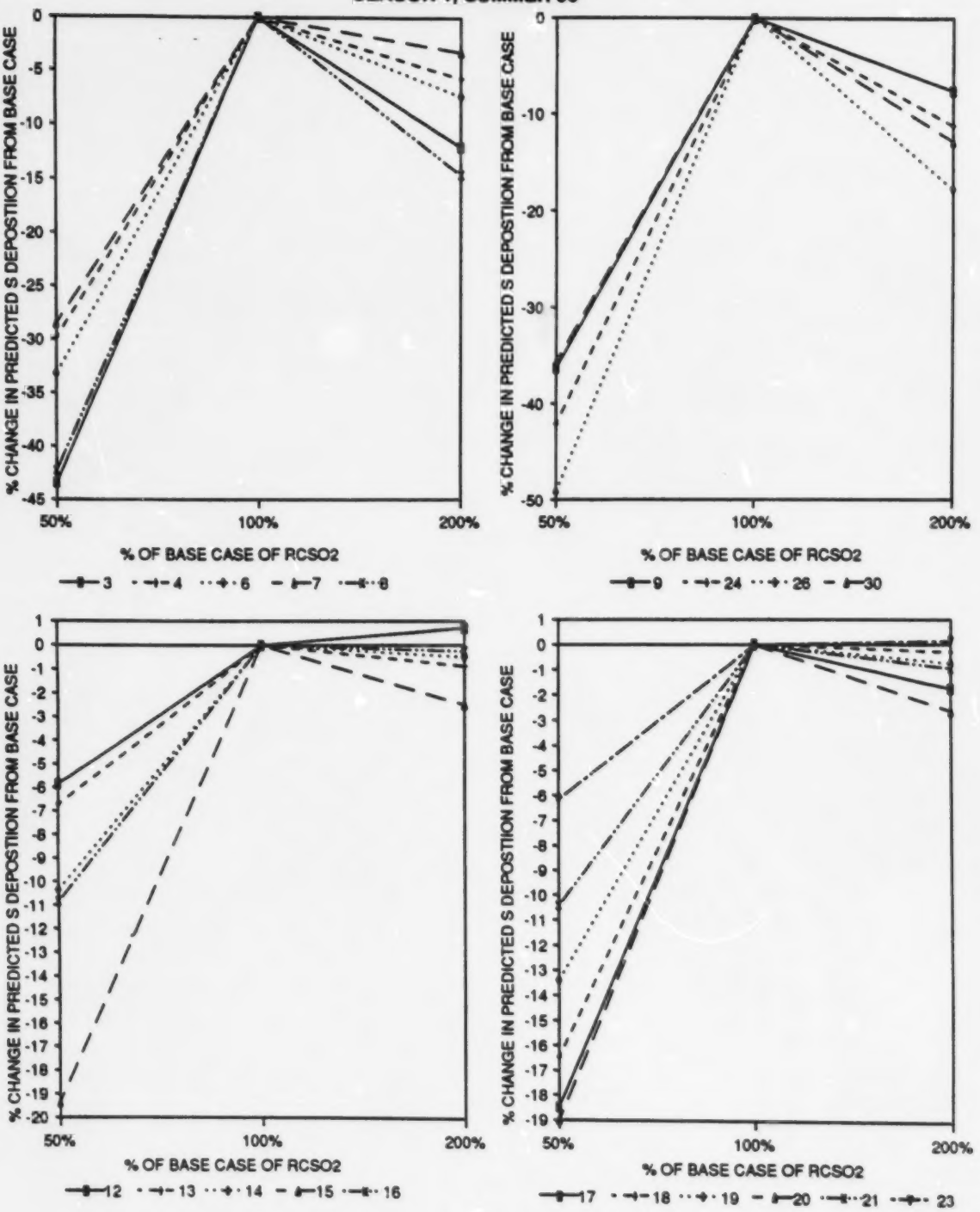


FIGURE 4-2
MESOPUFF II SENSITIVITY MODEL RESULTS OF PREDICTED SEASONAL WET S DEPOSITION DUE TO THE COLESON COVE AND N.B. SOUTH SOURCES
SEASON 2, FALL 88

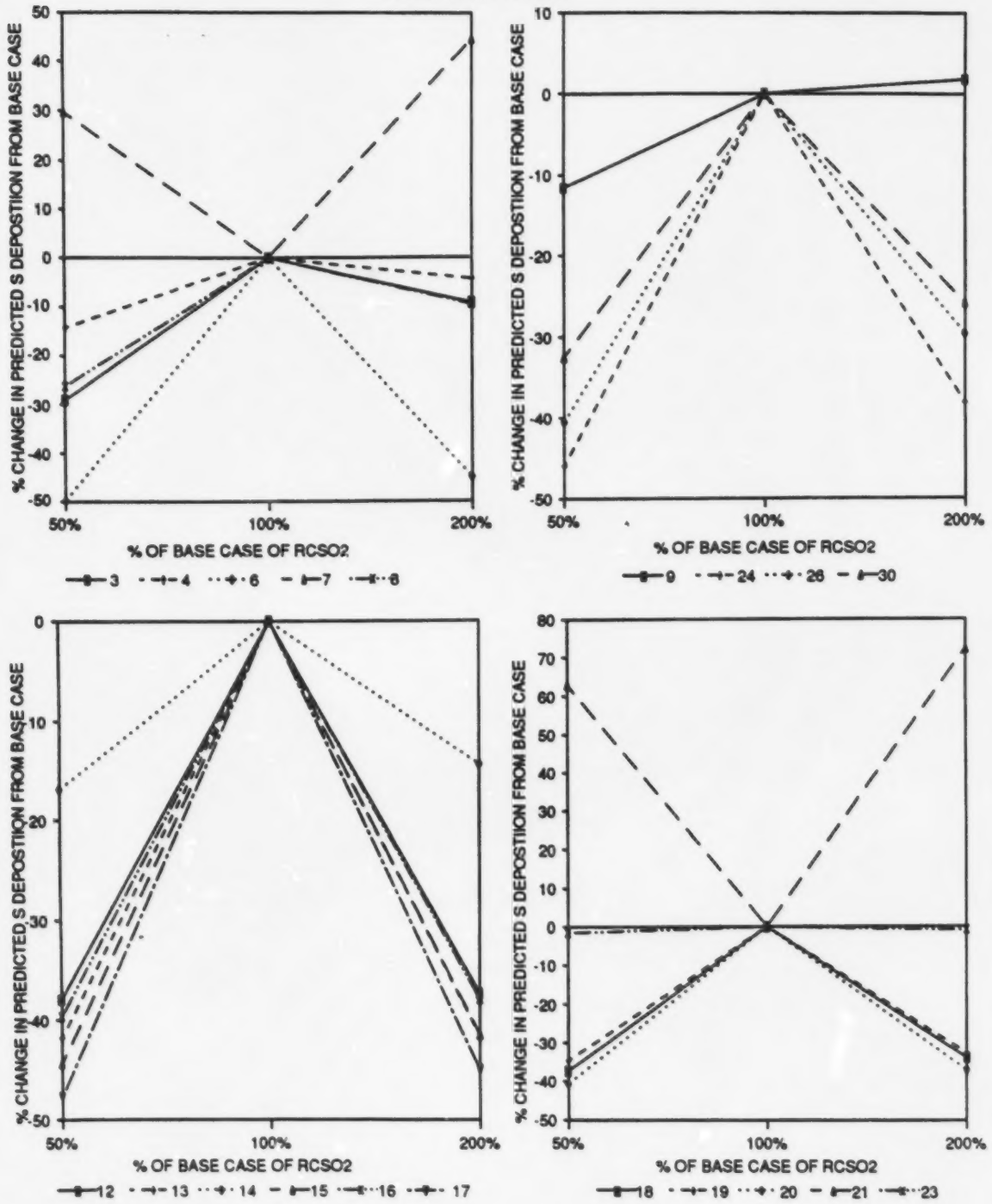
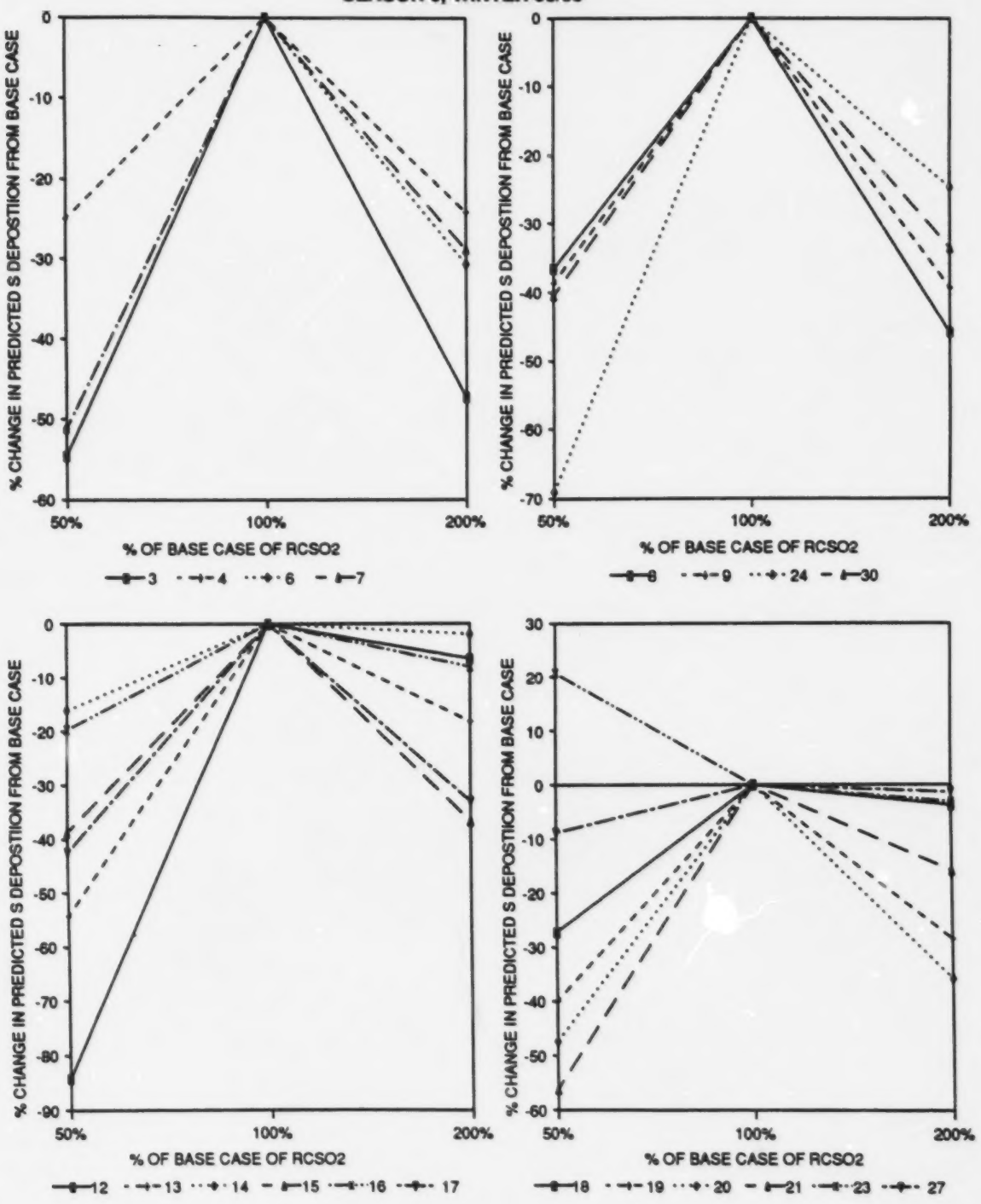


FIGURE 4-3
MESOPUFF II SENSITIVITY MODEL RESULTS OF PREDICTED SEASONAL WET S DEPOSITION DUE TO THE COLESON COVE AND N.B. SOUTH SOURCES
SEASON 3, WINTER 88/89



the adjusted observed wet excess sulphate (expressed as sulphur) deposition; the predicted sulphur deposition for each source group and the total predicted deposition, and the adjusted background as absolute amounts (Appendix 5.1) and as percentages (Appendix 5.2). Included also are mean values for all stations and for stations in the Coleson Cove-Saint John area.

Analysis of the model predictions involved determination of the relative contribution of the source groups (especially the Coleson Cove TGS alone) to wet deposition at stations in the Coleson Cove-Saint John area, and also analysis of the relationship between model predictions and wet deposition measurements.

Relative Contribution of Source Groups and background to Wet Deposition

Segmented bar charts showing the contribution of the four source groups and the inferred background to the total predicted deposition are shown in Figures 4-4 to 4-11 for seasons 1 to 8, respectively, and for each year (Figure 4-12). Similar bar graphs for the **incremental** seasonal wet sulphur deposition (i.e., the model prediction alone without background) are given in Appendix 5.3. In all data and figures depicting the wet S deposition, it should be noted that wet deposition expressed as sulphate would be 3 times higher. Table 4-4 summarizes for each season, the predicted source group contributions to wet sulphur deposition at all receptors and at receptors in the Coleson Cove-Saint John area. Table 4-4A shows the contribution in terms of S deposition (kg S/ha/y) and Table 4-4B shows the percentage contributions.

The Coleson Cove TGS is predicted to contribute between 7.0% and 16.3% to the seasonal wet sulphur deposition (including the background) at receptors in the Coleson Cove-Saint John area (see Table 4-4B). The remaining sources in the south of New Brunswick - primarily in the Saint John area, are predicted to contribute between 1.7% and 15.3% percent to seasonal wet sulphur deposition at receptors in the Coleson Cove-Saint John area. The predicted seasonal wet deposition estimates are variable as are the observed wet S deposition. Annual

FIGURE 4-4

SOURCE GROUP CONTRIBUTIONS TO PREDICTED SEASONAL WET SULPHUR DEPOSITION
SEASON 1, SUMMER 88

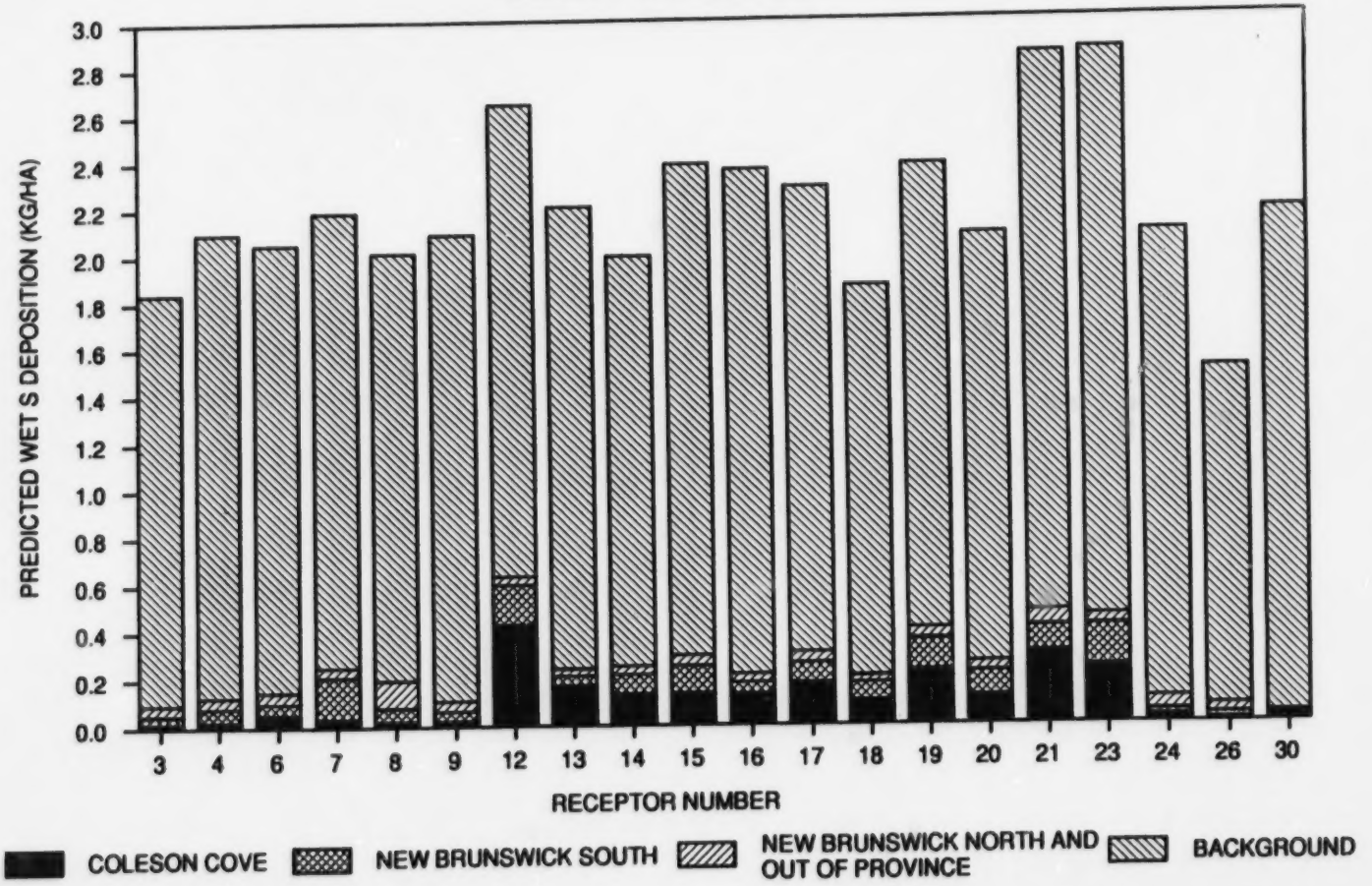


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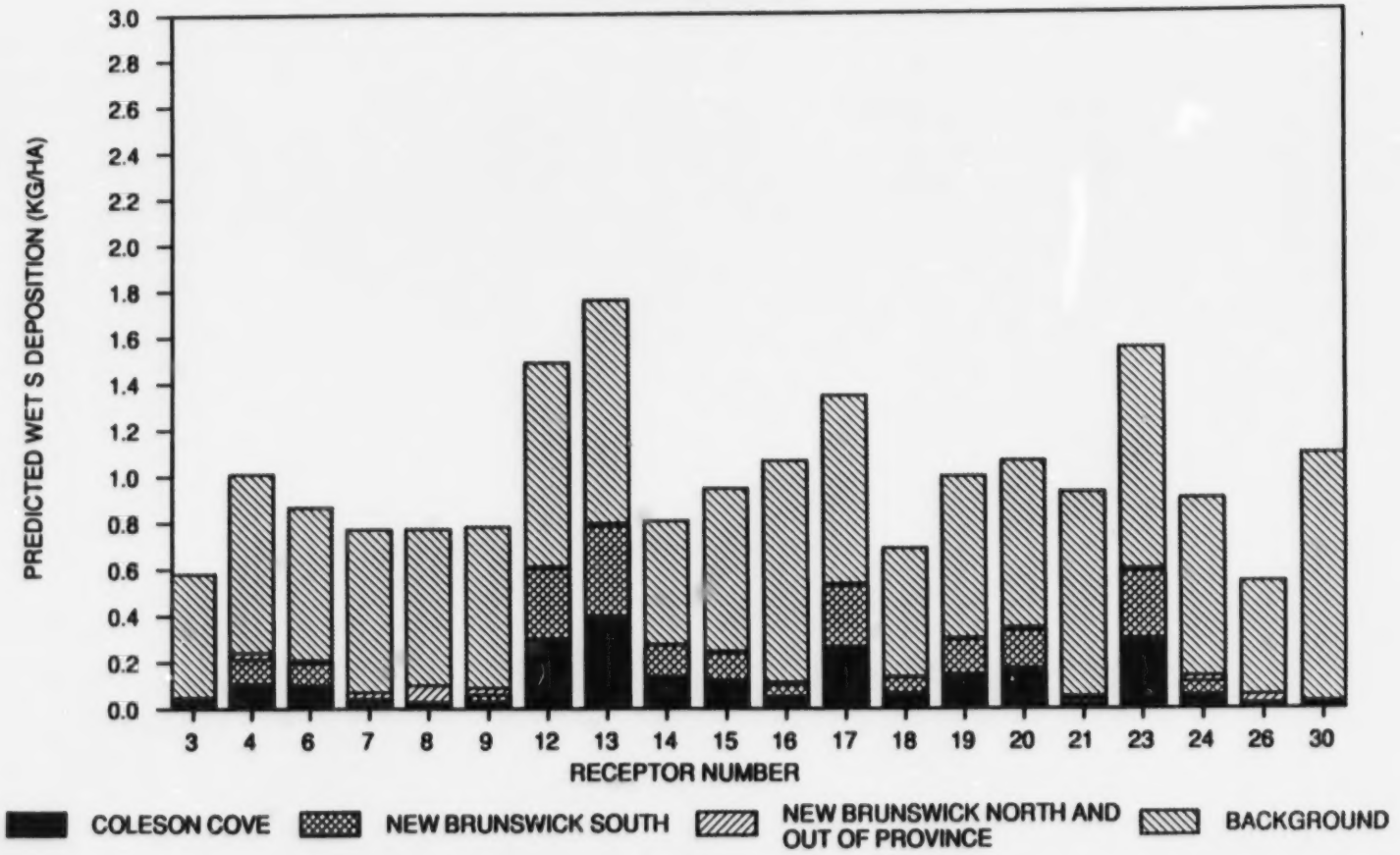
FIGURE 4-5

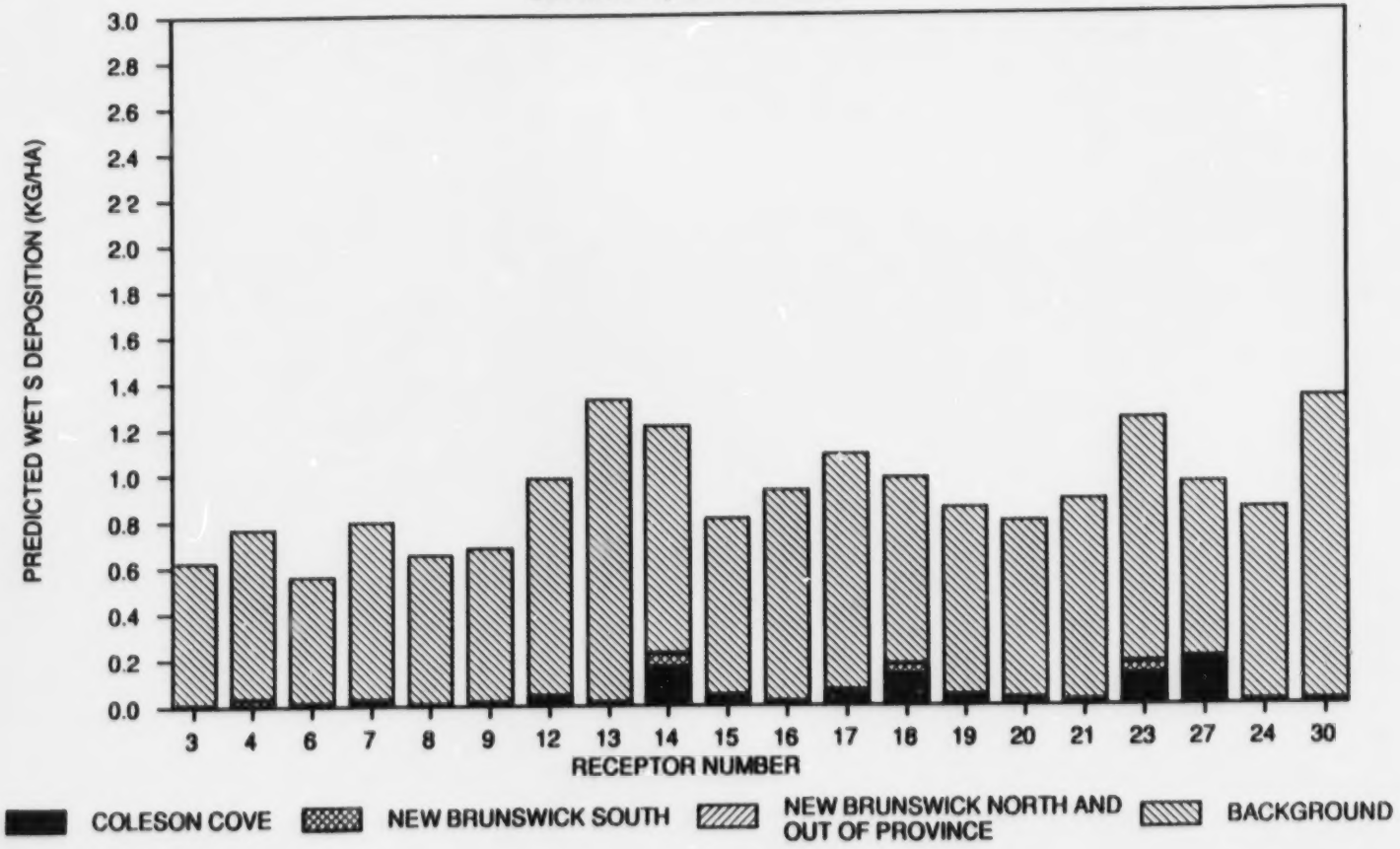
SOURCE GROUP CONTRIBUTIONS TO PREDICTED SEASONAL WET SULPHUR DEPOSITION
SEASON 2, FALL 88



CONCORD ENVIRONMENTAL

FIGURE 4-6

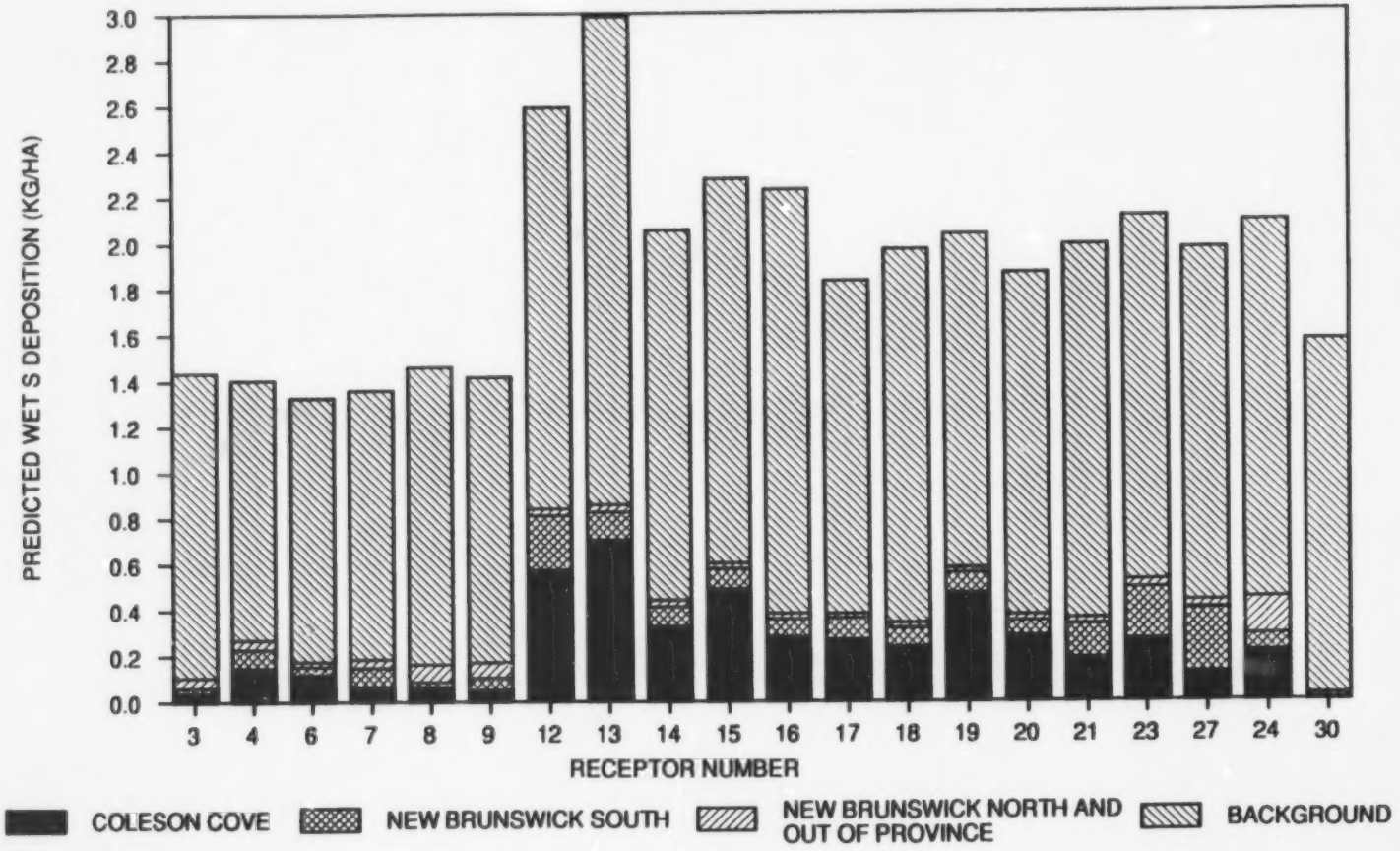
SOURCE GROUP CONTRIBUTIONS TO PREDICTED SEASONAL WET SULPHUR DEPOSITION
SEASON 3, WINTER 88/89



CONCORD ENVIRONMENTAL

FIGURE 4-7

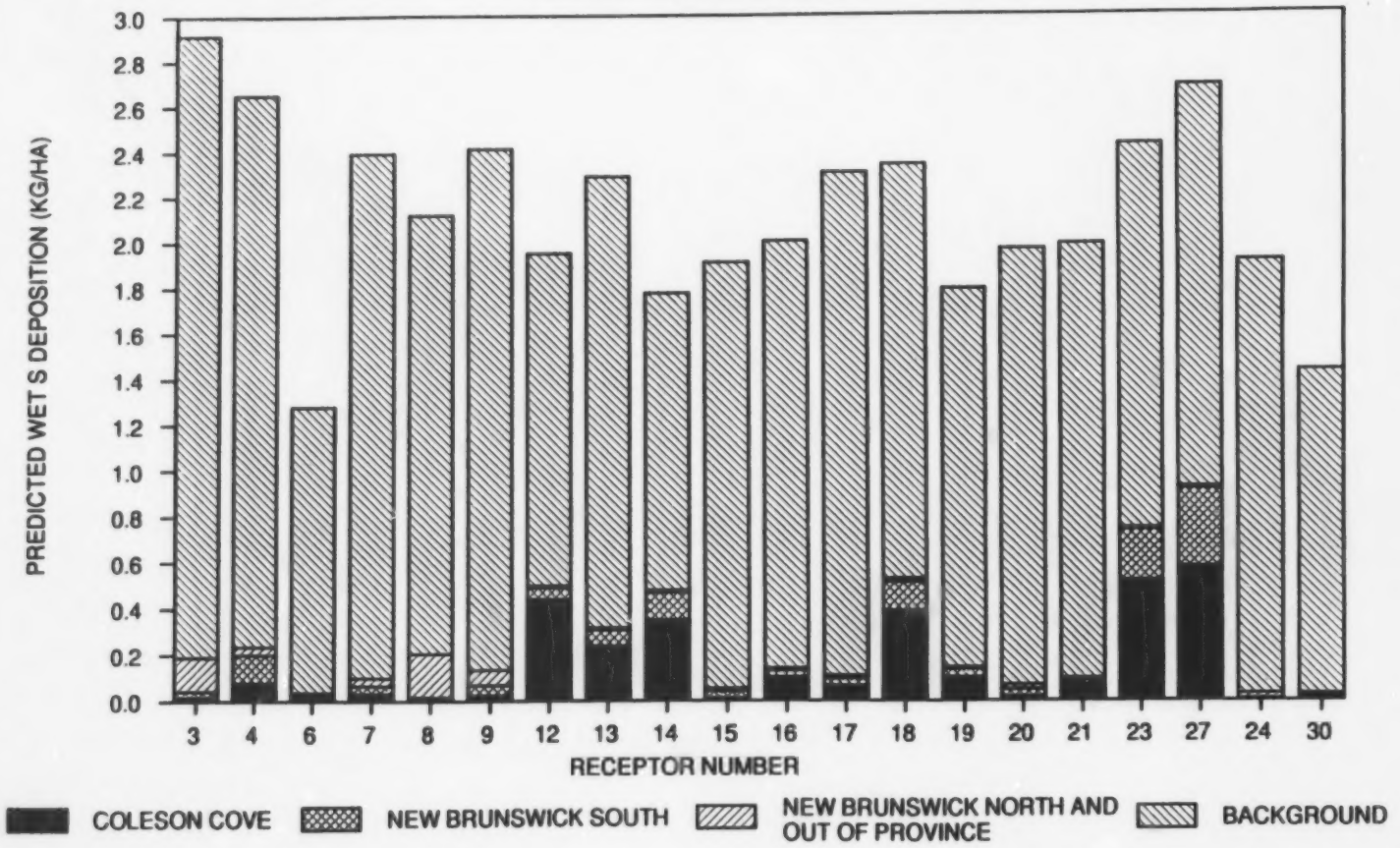
SOURCE GROUP CONTRIBUTIONS TO PREDICTED SEASONAL WET SULPHUR DEPOSITION
SEASON 4, SPRING 89



CONCORD ENVIRONMENTAL

FIGURE 4-8

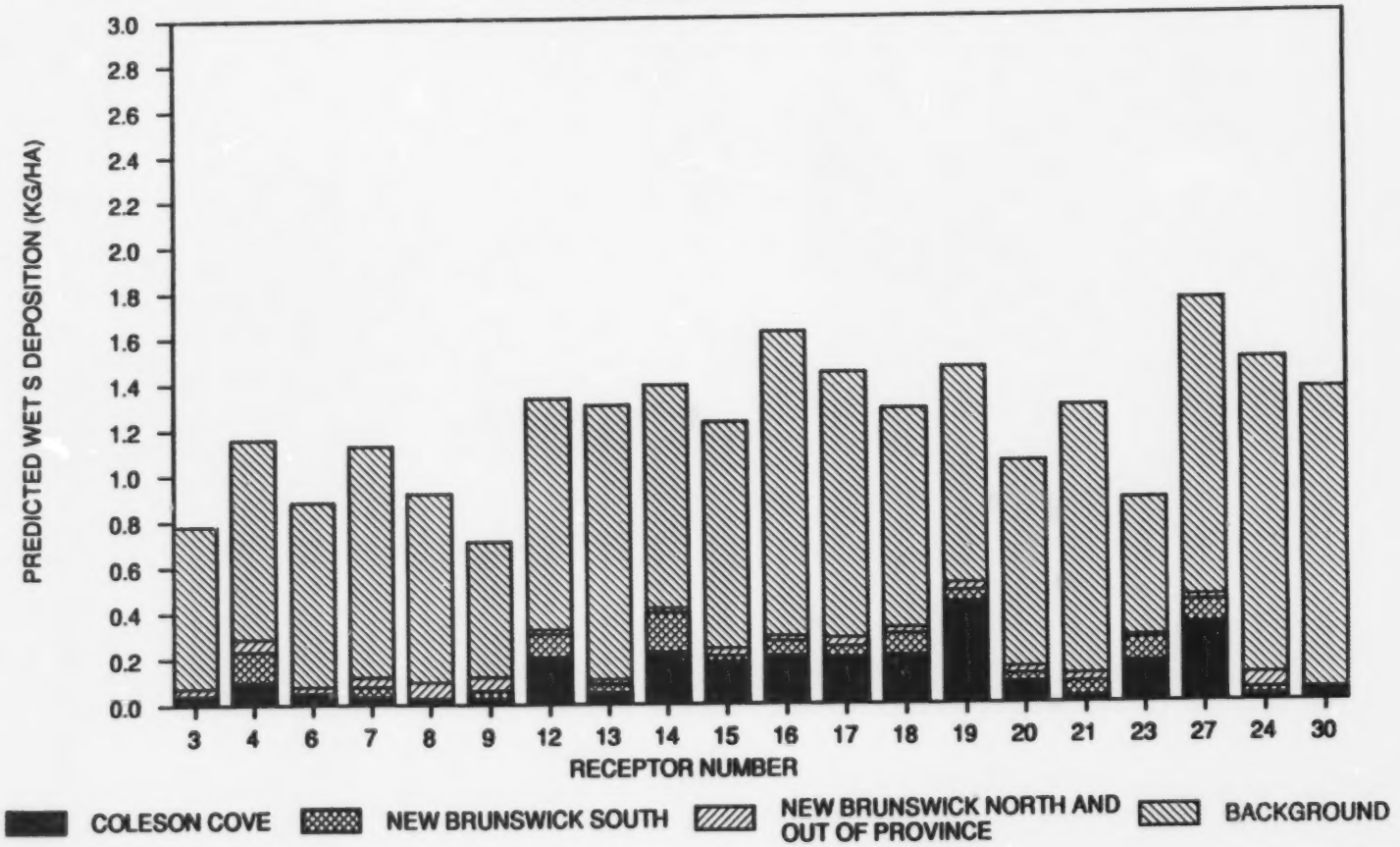
SOURCE GROUP CONTRIBUTIONS TO PREDICTED SEASONAL WET SULPHUR DEPOSITION
SEASON 5, SUMMER 89



CONCORD ENVIRONMENTAL

FIGURE 4-9

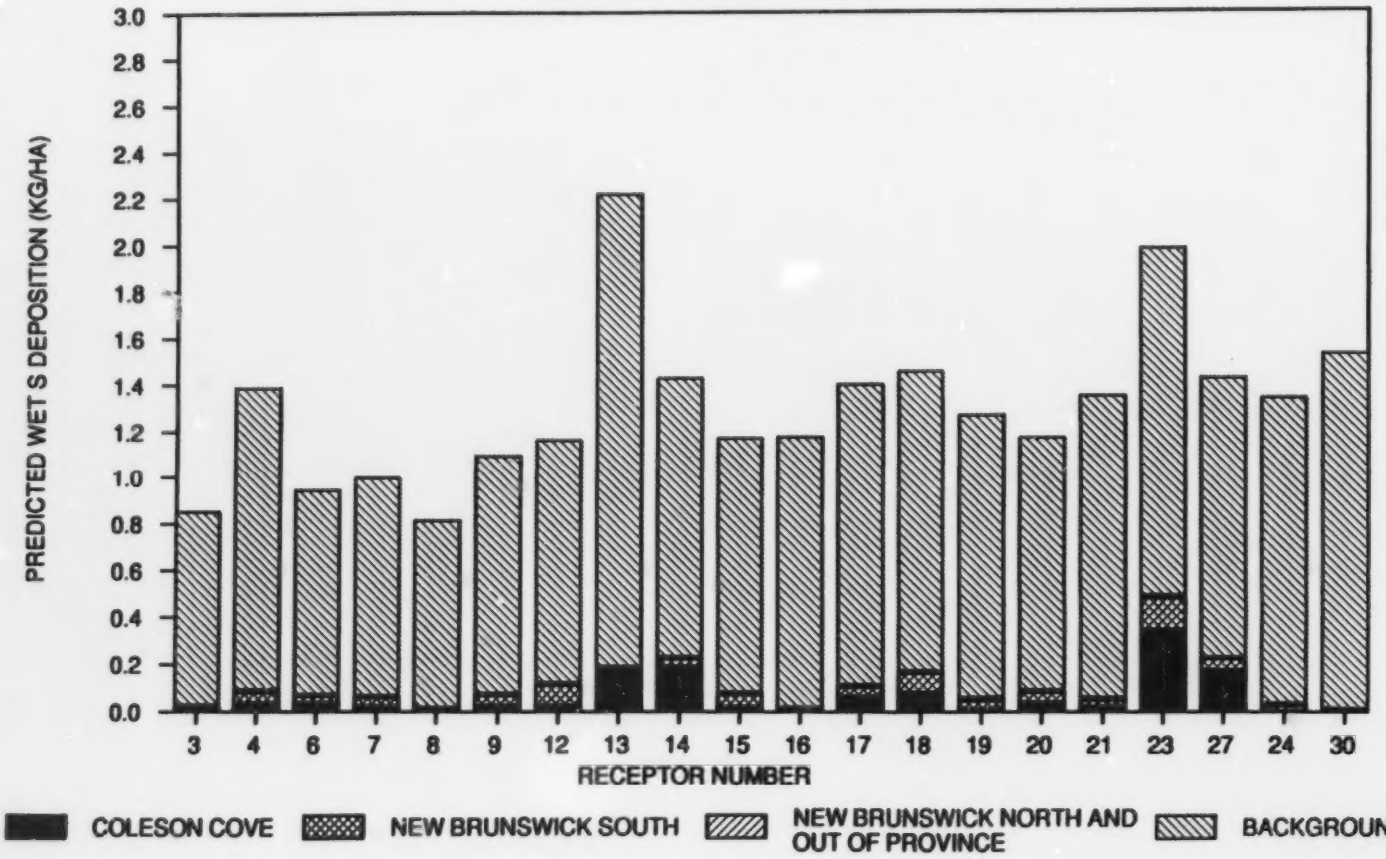
SOURCE GROUP CONTRIBUTIONS TO PREDICTED SEASONAL WET SULPHUR DEPOSITION
SEASON 6, FALL 89



CONCORD ENVIRONMENTAL

FIGURE 4-10

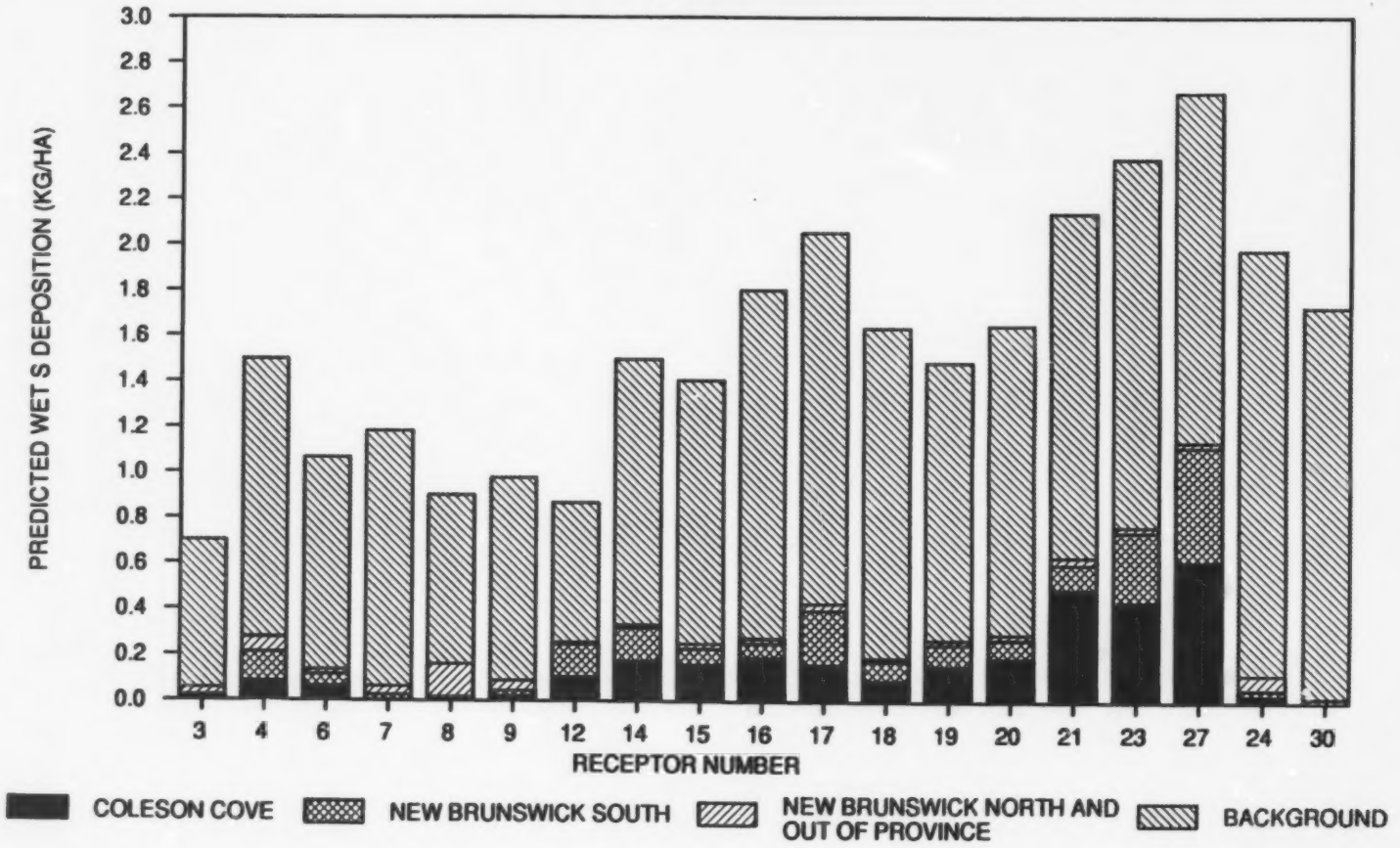
SOURCE GROUP CONTRIBUTIONS TO PREDICTED SEASONAL WET SULPHUR DEPOSITION
SEASON 7, WINTER 89/90



CONCORD ENVIRONMENTAL

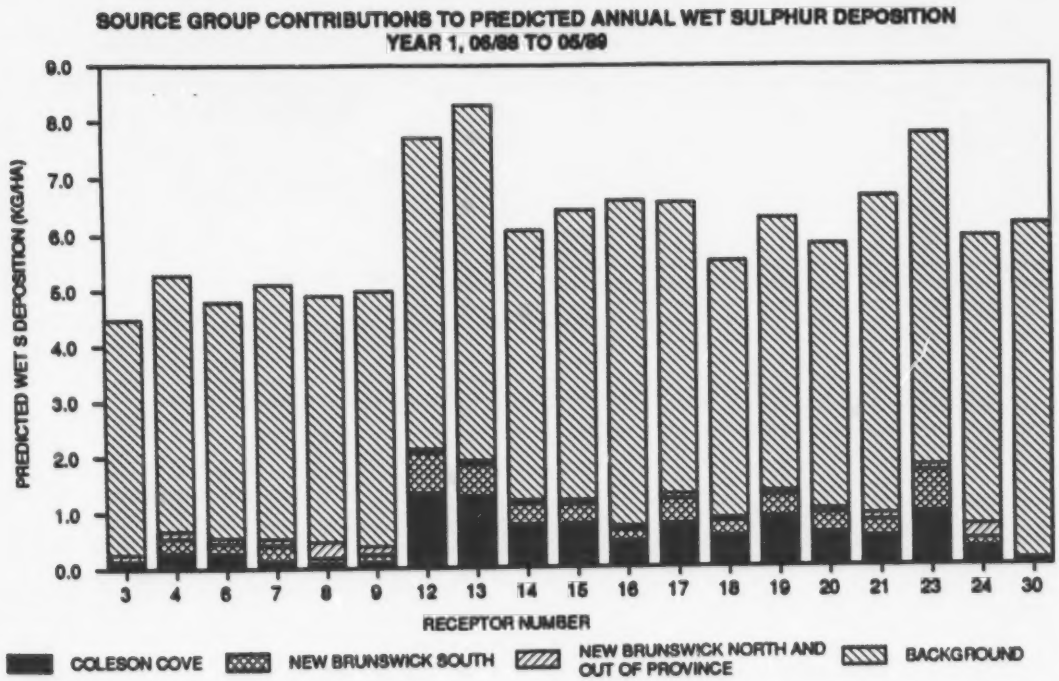
FIGURE 4-11

SOURCE GROUP CONTRIBUTIONS TO PREDICTED SEASONAL WET SULPHUR DEPOSITION
SEASON 8, SPRING 90



CONCORD ENVIRONMENTAL

FIGURE 4-12


SOURCE GROUP CONTRIBUTIONS TO PREDICTED ANNUAL WET SULPHUR DEPOSITION
YEAR 1, 06/88 TO 05/89
PREDICTED WET S DEPOSITION (KG/HA)
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
3 4 6 7 8 9 12 13 14 15 16 17 18 19 20 21 23 24 30
RECEPTOR NUMBER
COLESON COVE
NEW BRUNSWICK SOUTH
NEW BRUNSWICK NORTH AND OUT OF PROVINCE
BACKGROUND

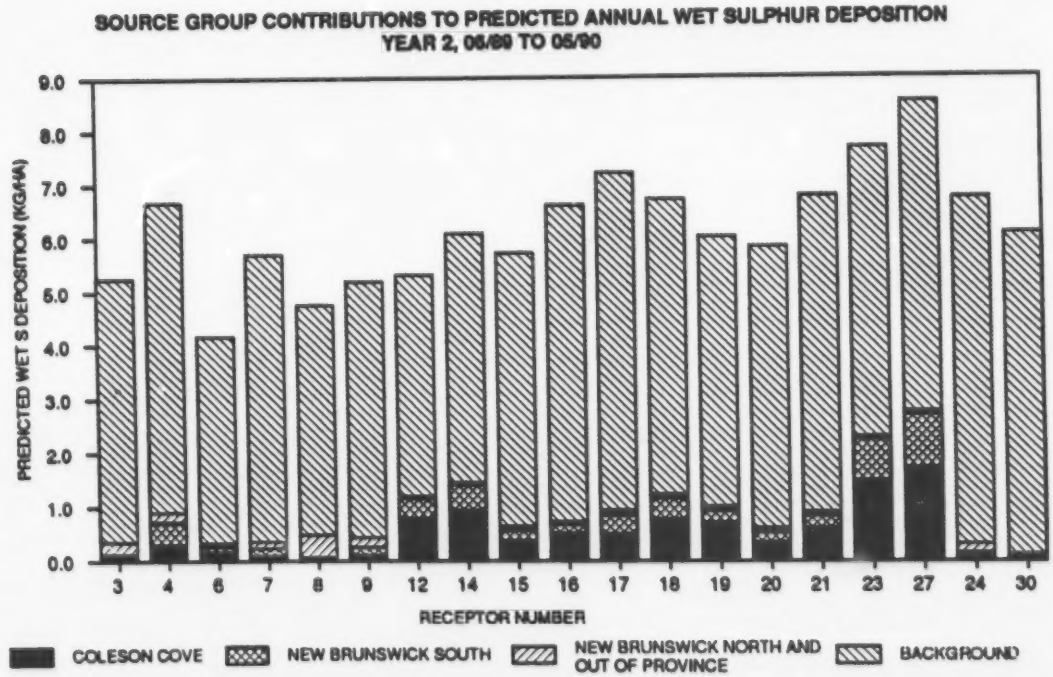

SOURCE GROUP CONTRIBUTIONS TO PREDICTED ANNUAL WET SULPHUR DEPOSITION
YEAR 2, 06/89 TO 05/90
PREDICTED WET S DEPOSITION (KG/HA)
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
3 4 6 7 8 9 12 14 15 16 17 18 19 20 21 23 27 24 30
RECEPTOR NUMBER
COLESON COVE
NEW BRUNSWICK SOUTH
NEW BRUNSWICK NORTH AND OUT OF PROVINCE
BACKGROUND

TABLE 4-4A

AVERAGE WET SULPHUR DEPOSITION (kg/ha)
SOURCE GROUP AVERAGE CONTRIBUTIONS TO PREDICTED (INCUDING BACKGROUND)
SEASONAL WET SULPHUR DEPOSITION

SEASON		ALL RECEPTORS						COLESON COVE/SAINT JOHN RECEPTORS				
NO	DESCRIPTION	CC	NBS	NBN	OOP	BKGRD	TOTAL	CC	NBS	NBN	OOP	BKGRD
1	SUMMER 88	0.12	0.06	0.01	0.03	1.95	2.20	0.20	0.10	0.00	0.04	2.01
2	FALL 88	0.12	0.11	0.01	0.01	0.75	1.00	0.18	0.18	0.00	0.01	0.78
3	WINTER 88/89	0.05	0.01	0.00	0.00	0.85	0.92	0.07	0.02	0.00	0.00	0.91
4	SPRING 89	0.25	0.10	0.01	0.03	1.51	1.90	0.35	0.13	0.00	0.02	1.65
5	SUMMER 89	0.16	0.07	0.02	0.01	1.87	2.13	0.24	0.09	0.00	0.01	1.78
6	FALL 89	0.13	0.06	0.01	0.02	1.00	1.23	0.20	0.07	0.01	0.02	1.04
7	WINTER 89/90	0.07	0.04	0.00	0.01	1.19	1.31	0.10	0.05	0.00	0.01	1.27
8	SPRING 90	0.16	0.11	0.01	0.02	1.26	1.56	0.25	0.17	0.00	0.02	1.34
	YEAR 1	0.54	0.30	0.04	0.07	5.11	6.07	0.81	0.41	0.01	0.08	5.38
	YEAR 2	0.51	0.28	0.05	0.06	5.26	6.17	0.80	0.39	0.02	0.06	5.34

TABLE 4-4B
AVERAGE PERCENTAGE CONTRIBUTION OF SOURCE GROUPS
TO PREDICTED (INCLUDING BACKGROUND) SEASONAL WET SULPHUR DEPOSITION

SEASON		ALL RECEPTORS					COLESON COVE/SAINT JOHN RECEPTORS				
NO	DESCRIPTION	CC	NBS	NBN	OOP	BKGRD	CC	NBS	NBN	OOP	BKGRD
1	SUMMER 88	5.50	3.64	0.63	1.42	88.81	8.43	4.35	0.11	1.63	85.48
2	FALL 88	11.83	11.42	0.77	1.11	74.88	15.73	15.27	0.17	0.71	68.12
3	WINTER 88/89	4.93	1.42	0.18	0.50	92.97	7.02	1.65	0.10	0.50	90.74
4	SPRING 89	13.05	5.15	0.70	1.40	79.70	16.34	6.13	0.11	1.15	76.27
5	SUMMER 89	7.32	3.15	0.96	0.58	87.97	11.44	4.26	0.11	0.47	83.72
6	FALL 89	10.80	4.84	1.11	1.65	81.61	14.70	5.53	0.59	1.30	77.88
7	WINTER 89/90	5.24	2.88	0.33	0.59	90.97	7.04	3.33	0.23	0.61	88.79
8	SPRING 90	10.12	7.10	0.76	1.48	80.54	14.21	9.33	0.14	1.08	75.23
	YEAR 1	8.94	5.01	0.58	1.22	84.24	12.15	6.19	0.12	1.13	80.41
	YEAR 2	8.26	4.50	0.84	1.04	85.36	12.15	5.87	0.25	0.85	80.89

SOURCES ARE GROUPED TOGETHER AS FOLLOWS:
- CC = COLESON COVE TGS ALONE
- NBS = SOURCES IN NEW BRUNSWICK SOUTH
- NBN = SOURCES IN NEW BRUNSWICK NORTH
- OOP = SOURCES OUTSIDE NEW BRUNSWICK

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wet S deposition provides a more meaningful measure of impacts hence target loadings for wet deposition are expressed as annual loadings. The predicted annual wet S deposition indicates that the Coleson Cove TGS would contribute an average of 12.2% to wet S deposition at receptors in the Coleson Cove-Saint John area. The average annual background contribution to wet S deposition at receptors in the Coleson Cove-Saint John area is 81%. The dominant influence of the background is clear.

The relative contributions of the various source groups is best determined by examination of the incremental bar graphs in Appendix 5.3. The relative contribution of the Coleson Cove TGS to the **incremental** wet deposition at receptors in the Coleson Cove-Saint John area is predicted to be 49% to 76% (see Table 4-5). Similarly, the New Brunswick south sources are predicted to contribute about half as much (18% - 48%) to the incremental wet deposition in the Coleson Cove-Saint John area. As expected, out of province sources in the model domain contribute a small amount (2% to 11%) to the incremental wet S deposition (see Table 4-5).

Seasonal Scatter Plots and Regression Analyses

Scatter plots of the observed wet sulphur deposition versus the predicted deposition (including the background estimate) for each season are presented in Appendix 6. A summary of the regression parameters is given in Table 4-6. Regressions were calculated for all receptors and for receptors in the Coleson Cove - Saint John area. When <u>all</u> receptors were considered, the correlations were good for 7 of the eight seasons; for these seasons, the square of the correlation coefficients ranged from 0.2 to 0.7 (corresponding to R values of 0.44 to 0.84). For comparison, a Pearson correlation coefficient, R, of 0.49 was obtained for the LERTAD model runs for a two week period (Fung et al., 1988). Analogous Pearson correlation coefficients of 0.34 and 0.75 were obtained for

TABLE 4-5

AVERAGE PERCENTAGE CONTRIBUTION OF SOURCE GROUPS TO PREDICTED (EXCLUDING BACKGROUND) SEASONAL WET SULPHUR DEPOSITION

SEASON NO	SEASON	AVERAGE PERCENTAGE CONTRIBUTION (%)							
		ALL RECEPTORS				COLESON COVE/SAINT JOHN RECEPTORS			
		CC	NBS	NBN	OOP	CC	NBS	NBN	OOP
1	SUMMER 88	49.2	32.5	5.6	12.6	58.0	30.0	0.8	11.2
2	FALL 88	47.1	45.4	3.1	4.4	49.3	47.9	0.5	2.2
3	WINTER 88/89	70.1	20.2	2.5	7.1	75.8	17.8	1.1	5.3
4	SPRING 89	64.3	25.4	3.4	6.9	68.9	25.8	0.5	4.8
5	SUMMER 89	60.8	26.2	8.2	4.8	70.3	26.1	0.7	2.9
6	FALL 89	58.7	26.3	6.0	9.0	66.4	25.0	2.7	5.9
7	WINTER 89/90	58.0	31.9	3.6	6.5	62.8	29.7	2.1	5.4
8	SPRING 90	52.0	36.5	3.9	7.6	57.4	37.7	0.6	4.4
YEAR 1		56.7	31.8	3.7	7.8	62.0	31.6	0.6	5.8
YEAR 2		56.4	30.7	5.8	7.1	63.5	30.7	1.3	4.4

SOURCES ARE GROUPED TOGETHER AS FOLLOWS:

CC = COLESON COVE TGS ALONE
NBS = SOURCES IN NEW BRUNSWICK SOUTH
NBN = SOURCES IN NEW BRUNSWICK NORTH
OOP = SOURCES OUTSIDE NEW BRUNSWICK

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TABLE 4-6A

SUMMARY OF THE REGRESSION PARAMETERS FOR MEASURED
AND PREDICTED SEASONAL WET SULPHUR DEPOSITION FOR ALL RECEPTORS

	SUMMER 88	FALL 88	INTER 88/8	SPRING 89	SUMMER 89	FALL 89	INTER 89/9	SPRING 90
SLOPE	0.59	0.35	1.33	0.95	0.41	0.73	0.94	0.65
STD ERR OF SLOPE	0.27	0.17	0.21	0.17	0.38	0.21	0.23	0.14
Y-INTERCEPT	0.90	0.65	-0.31	0.10	1.25	0.33	0.08	0.55
STD ERR OF Y-INTERCEPT	0.39	0.23	0.20	0.33	0.68	0.26	0.34	0.32
R SQUARED	0.21	0.20	0.70	0.63	0.06	0.40	0.48	0.55
NO. OF OBSERVATIONS	20	20	20	20	20	20	20	19
DEGREES OF FREEDOM	18	18	18	18	18	18	18	17

TABLE 4-6B

SUMMARY OF THE REGRESSION PARAMETERS FOR MEASURED
AND PREDICTED SEASONAL WET SULPHUR DEPOSITION FOR COLESON COVE/SAINT JOHN RECEPTORS

	SUMMER 88	FALL 88	INTER 88/8	SPRING 89	SUMMER 89	FALL 89	INTER 89/9	SPRING 90
SLOPE	0.56	0.51	1.32	0.98	0.84	0.75	0.96	0.77
STD ERR OF SLOPE	0.27	0.20	0.28	0.30	0.48	0.36	0.25	0.15
Y-INTERCEPT	0.99	0.49	-0.19	0.09	1.08	0.34	0.17	0.42
STD ERR OF Y-INTERCEPT	0.28	0.21	0.16	0.33	0.38	0.28	0.27	0.24
R SQUARED	0.32	0.43	0.69	0.52	0.23	0.30	0.60	0.74
NO. OF OBSERVATIONS	11	11	12	12	12	12	12	11
DEGREES OF FREEDOM	9	9	10	10	10	10	10	9

SOURCES ARE GROUPED TOGETHER AS FOLLOWS:

CC = COLESON COVE TGS ALONE

NBS = SOURCES IN NEW BRUNSWICK SOUTH

NBN = SOURCES IN NEW BRUNSWICK NORTH

OOP = SOURCES OUTSIDE NEW BRUNSWICK

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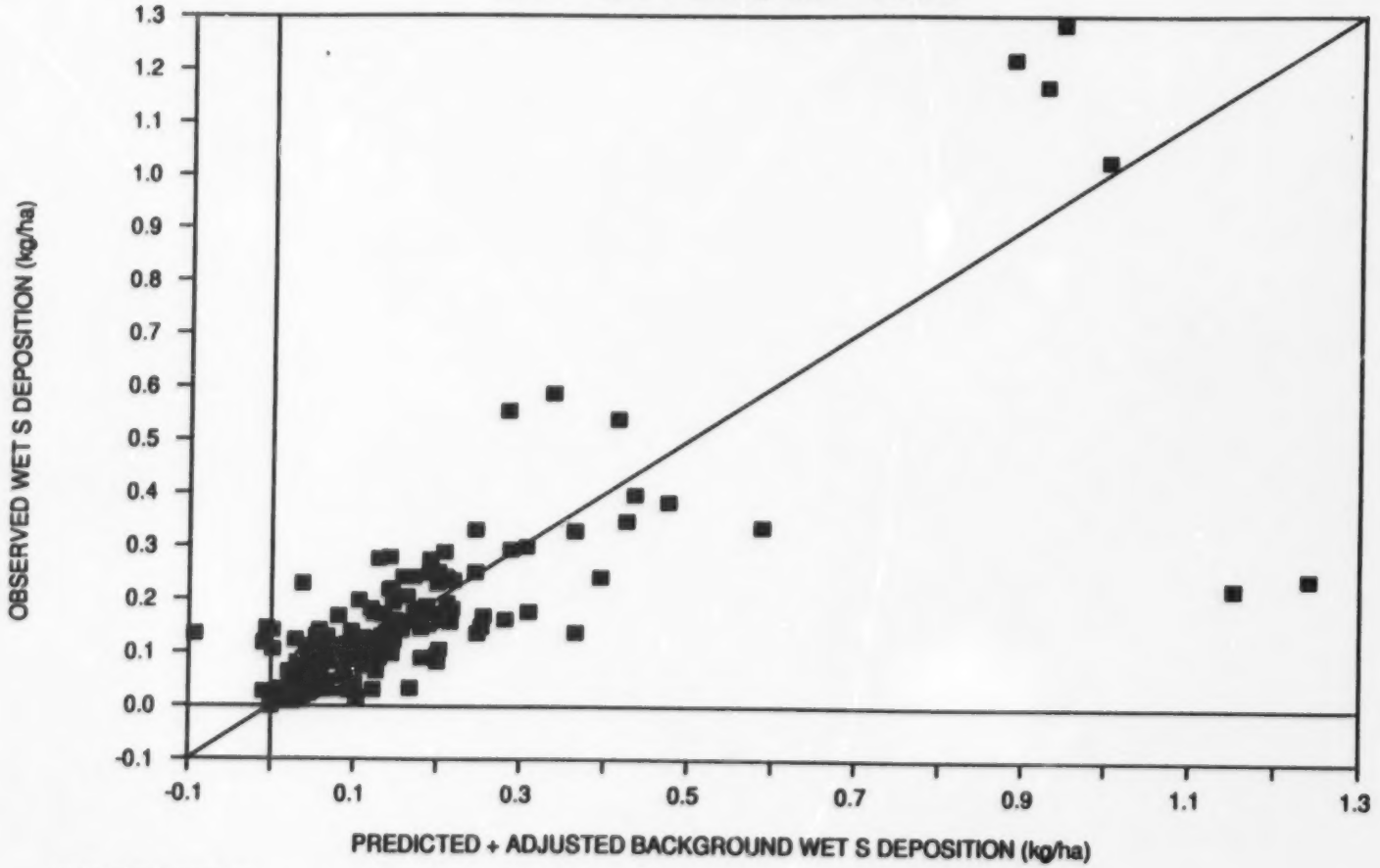
similar (Lagrangian puff) models (U.S. EPA, 1987) based on annual model predictions of wet sulphur deposition for eastern North America. In general, the results are considered good given the sparsity of meteorological data and in particular the precipitation data. In all cases all available data were included (i.e., for both model predictions and observations) thus there was no screening of the data for example by excluding outliers. Similar regressions for receptors in the Coleson Cove-Saint John area were good for all 8 seasons with R^2 values ranging from 0.23 to 0.74 corresponding to R of 0.48 to 0.86.

4.3.1.1 Weekly Scatter Plots For Sulphate Deposition

More detailed examination of the model predictions involved examining scatter plots and regressions of the weekly observations and predictions. An approach similar to that used in the seasonal case was to estimate the weekly background. The weekly background was taken as the mean of the difference between the observed deposition minus the predicted deposition multiplied by the ratio of the measured precipitation at each station in the week and the model input precipitation in the week. However, in view of the high spatial variability of precipitation, screening of the data was undertaken as follows. Only those observation/prediction pairs for which the model input precipitation was within ±25% of the observation (an arbitrarily selected level) were included in the regression or scatter plots. Figures 4-13 to 4-15 show scatter plots for weekly observed deposition against the predicted deposition for those cases where the ratio of the difference between the measured precipitation and the model input precipitation to the model input precipitation is ≤ 0.25 for both years (Figure 4-13) and for each year (Figures 4-14 and 4-15). Similar plots but with all data are given in Appendix 7. The R^2 values for weekly observations versus model predictions including the background were 0.56 for all data and 0.61 for cases where there was agreement within 25% for the measured and hourly precipitation model input data. The scatter plots are considered good but it must be borne in mind that the method used to determine the background to a large degree ensures that the agreement be good. Nevertheless, it should be noted that another means of choosing the background are likely to produce similar results. That is, once it is

FIGURE 4.13
SCATTER DIAGRAM FOR SELECTED(1) OBSERVED AND PREDICTED WEEKLY WET S DEPOSITION
YEAR 1 AND YEAR 2, 06/88 TO 05/90



(1) Criterion for selection:
Abs((measured precip - model input precip)/measured precip) <= 0.25
(2) Negative values for PREDICTED + ADJUSTED BACKGROUND arise when mean PREDICTED > OBSERVED wet S deposition and larger adjustments are needed to the background wet S deposition.

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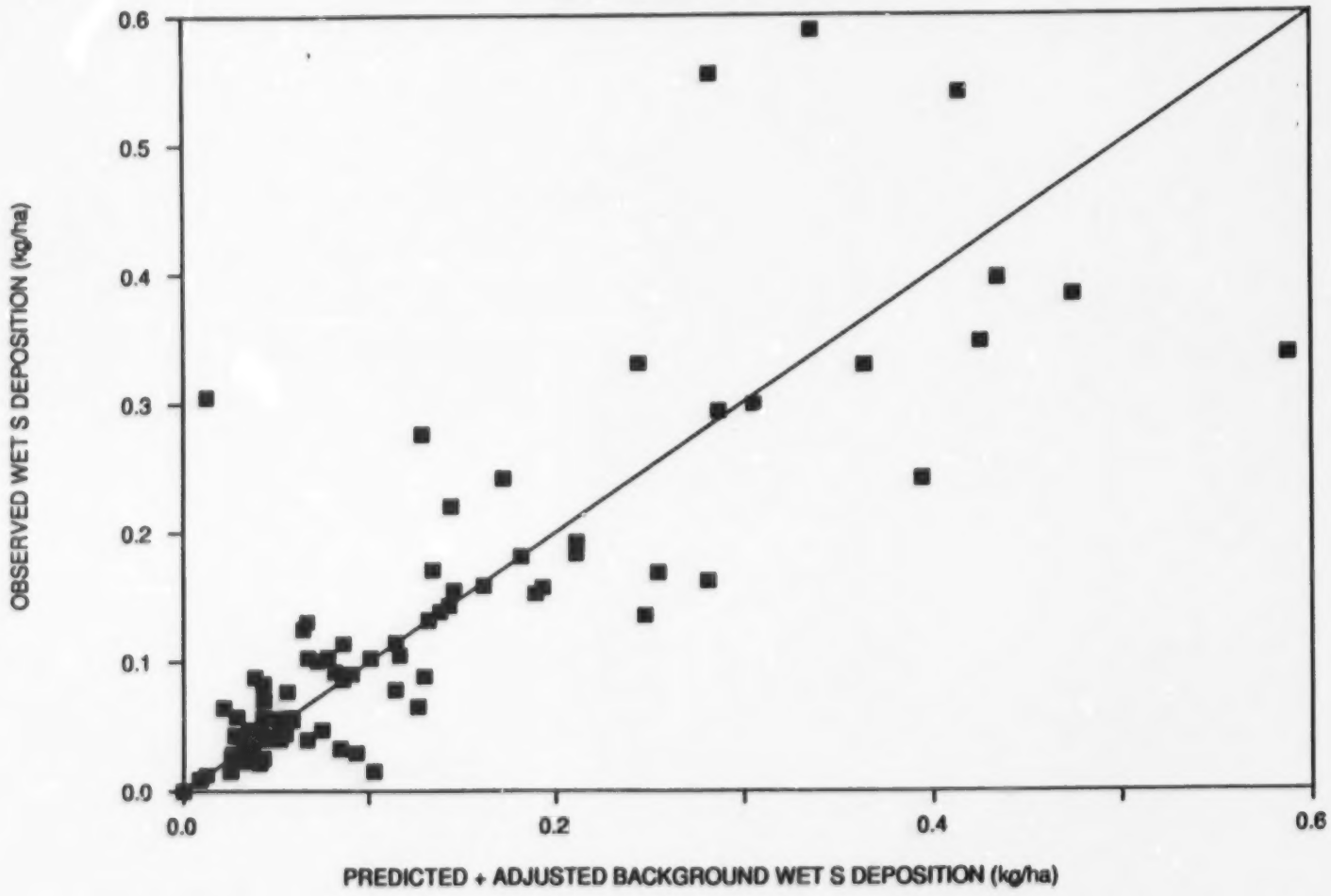
FIGURE 4.14
SCATTER DIAGRAM FOR SELECTED(1) OBSERVED AND PREDICTED WEEKLY WET S DEPOSITION
YEAR 1, 06/88 TO 05/89



(1) Criterion for selection:
Abs((measured precip - model input precip)/measured precip) <= 0.25

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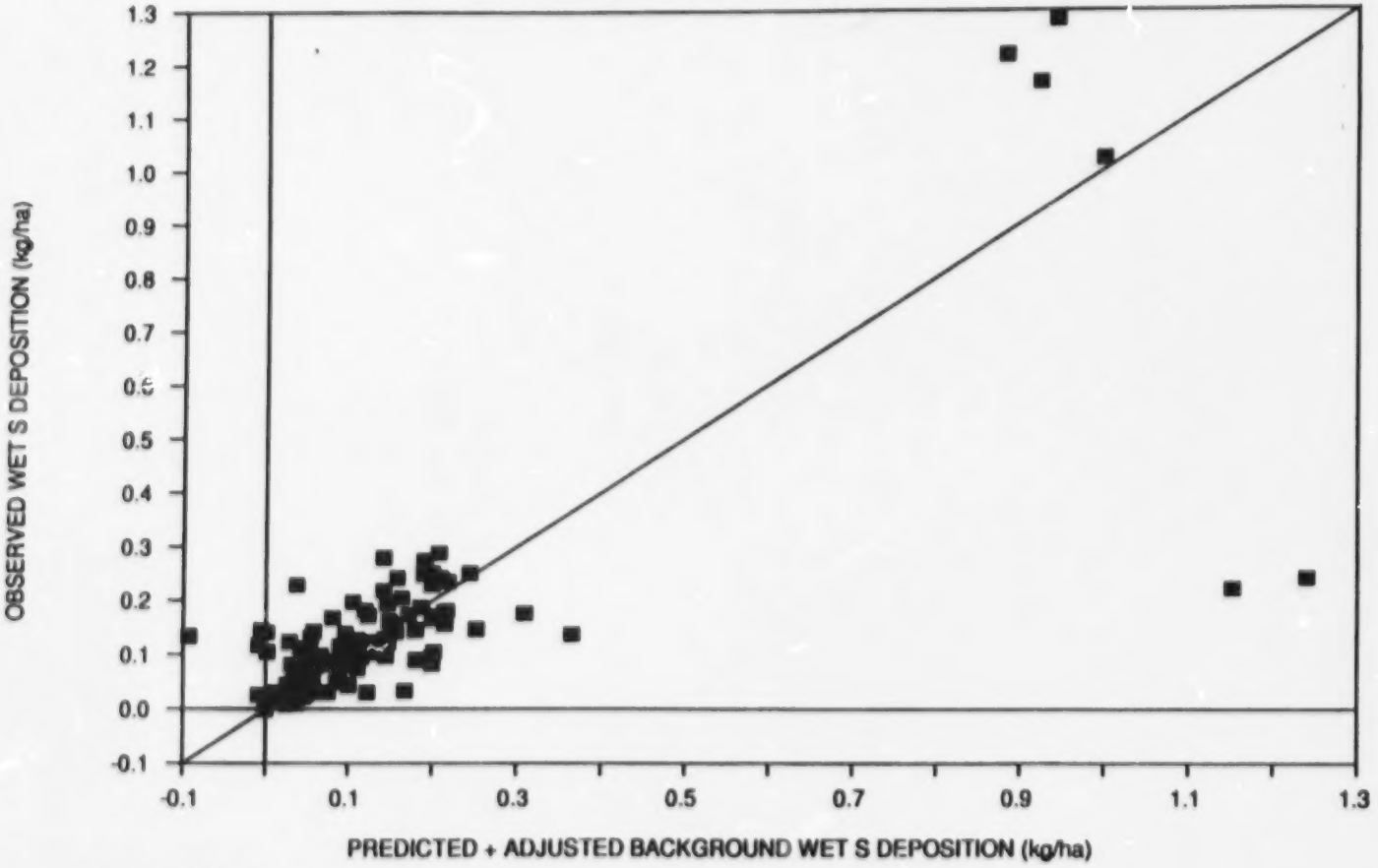
FIGURE 4.15
SCATTER DIAGRAM FOR SELECTED(1) OBSERVED AND PREDICTED WEEKLY WET S DEPOSITION
YEAR 2, 06/89 TO 05/90



(1) Criterion for selection:
Abs((measured precip - model input precip)/measured precip) <= 0.25
(2) Negative values for PREDICTED + ADJUSTED BACKGROUND arise when mean PREDICTED > OBSERVED wet S deposition and larger adjustments are needed to the background wet S deposition.

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accepted that the there is a consistent background concentration of SO_2 and $SO_4^=$, then the wet sulphur deposition will be dependent on the amount of precipitation. Thus selection of a scheme whereby the background is weighted by the amount of precipitation should provide similar results.

4.4 SPATIAL PATTERNS

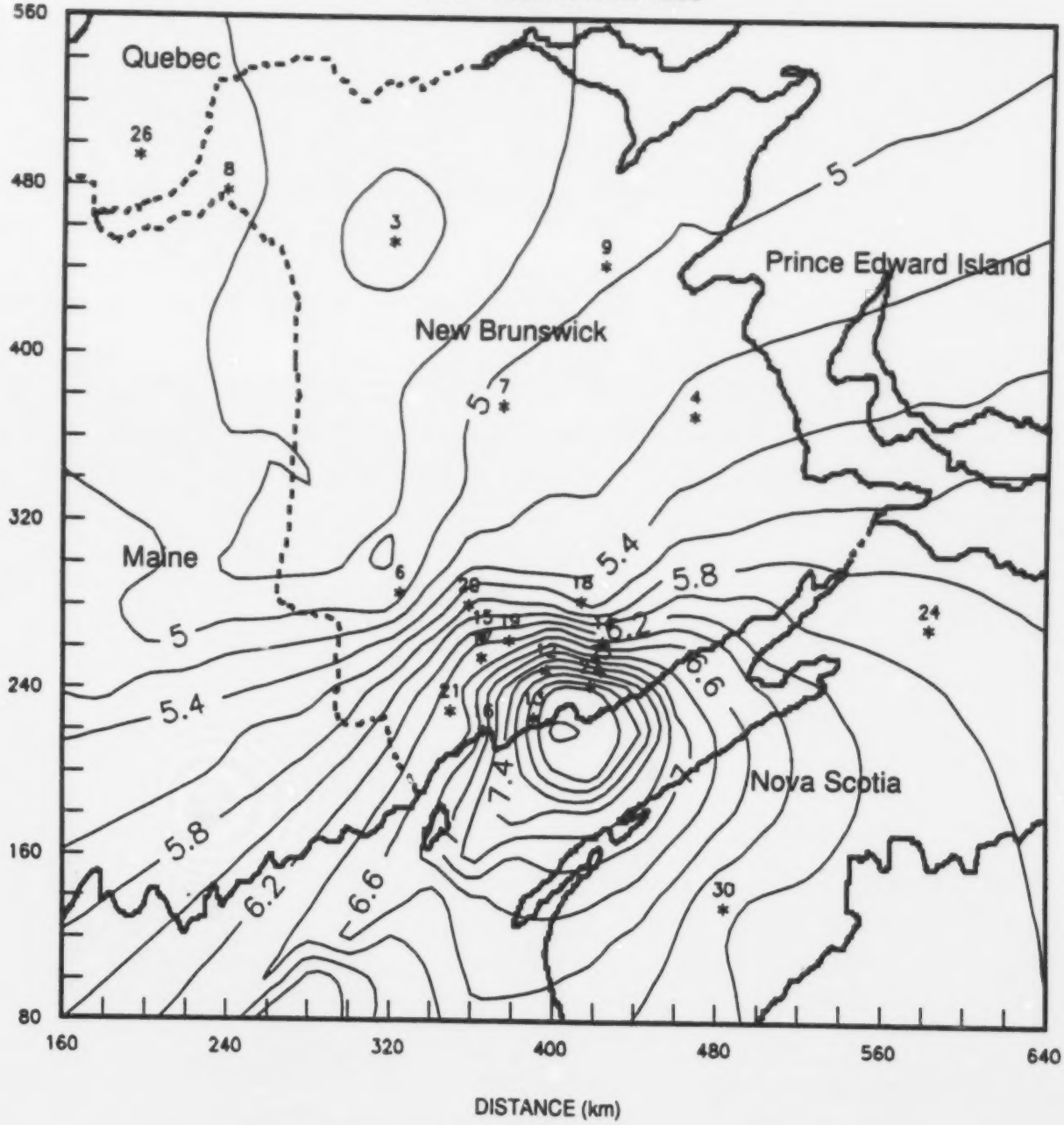
Isopleths showing the predicted annual wet sulphur deposition (including background) are shown in Figures 4-16 and 4-17. Isopleths were determined by an interpolation technique that included kriging using the graphics package SURFER. The spatial patterns in Figures 4-16 and 4-17 resemble those of the comparable isopleths based on measured wet deposition (Davis et al., 1991) as indicated in Figures 4-18 and 4-19. Detailed quantitative analysis on any differences in the spatial distribution was not conducted. It should be noted that the determination of the isopleths in Figures 4-16 to 4-19 were based on a similar set of receptors. There are no receptors over the ocean notably over the Bay of Fundy, thus the interpolated values over these areas should be considered with caution. It is entirely feasible to obtain model predictions for these areas (i.e., over the sea) but they would be determined largely by the precipitation amounts estimated for these regions. Such predictions would also have to be viewed with caution.

4.5 DISCUSSION

The application of the MESOPUFF II model to New Brunswick required compilation of source information as well as meteorological and land use data. Model predictions are of course very dependent on source and meteorological inputs thus assessment of these data is appropriate before commenting on model predictions.

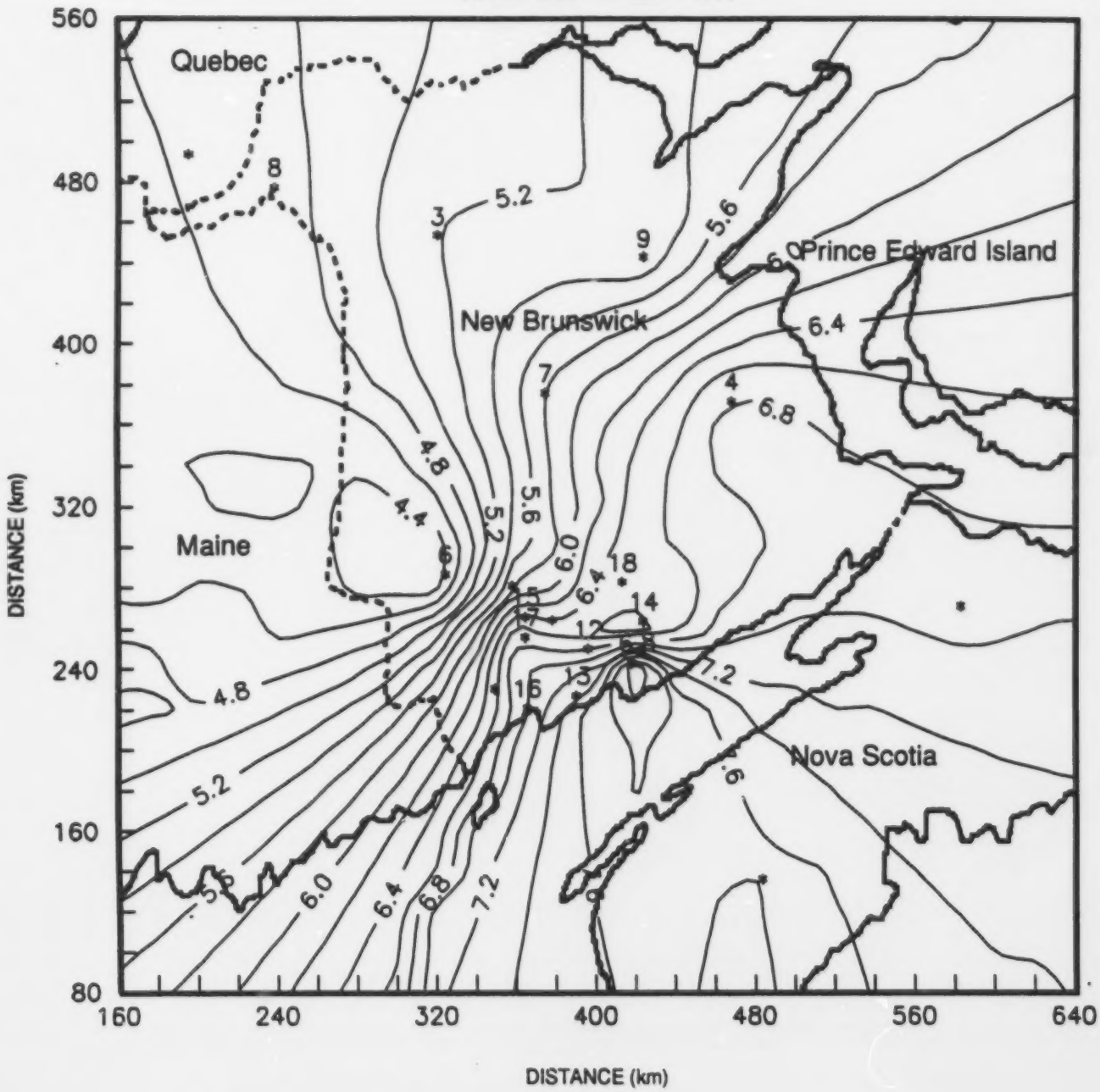
The meteorological data included upper air measurements at four stations. Three of the four stations are located in the west of the domain (Caribou and Portland in Maine; Sept Isles in Quebec) and one to the south (Shelbourne, N.S.). Given

FIGURE 4-16
PREDICTED S DEPOSITION(INCLUDING BACKGROUND) (kg/ha) FOR YEAR 1
JUNE 1988 TO MAY 1989



(1) Contours were generated based on the predicted deposition at the discrete receptors marked.

FIGURE 4-17
PREDICTED S DEPOSITION(INCLUDING BACKGROUND) (kg/ha) FOR YEAR 2
JUNE 1989 TO MAY 1990



(1) Contours were generated based on the predicted deposition at the discrete receptors marked.

FIGURE 4-18

ANNUAL SULPHATE DEPOSITION (kg/ha) FOR YEAR 1
JUNE 1988 TO MAY 1989

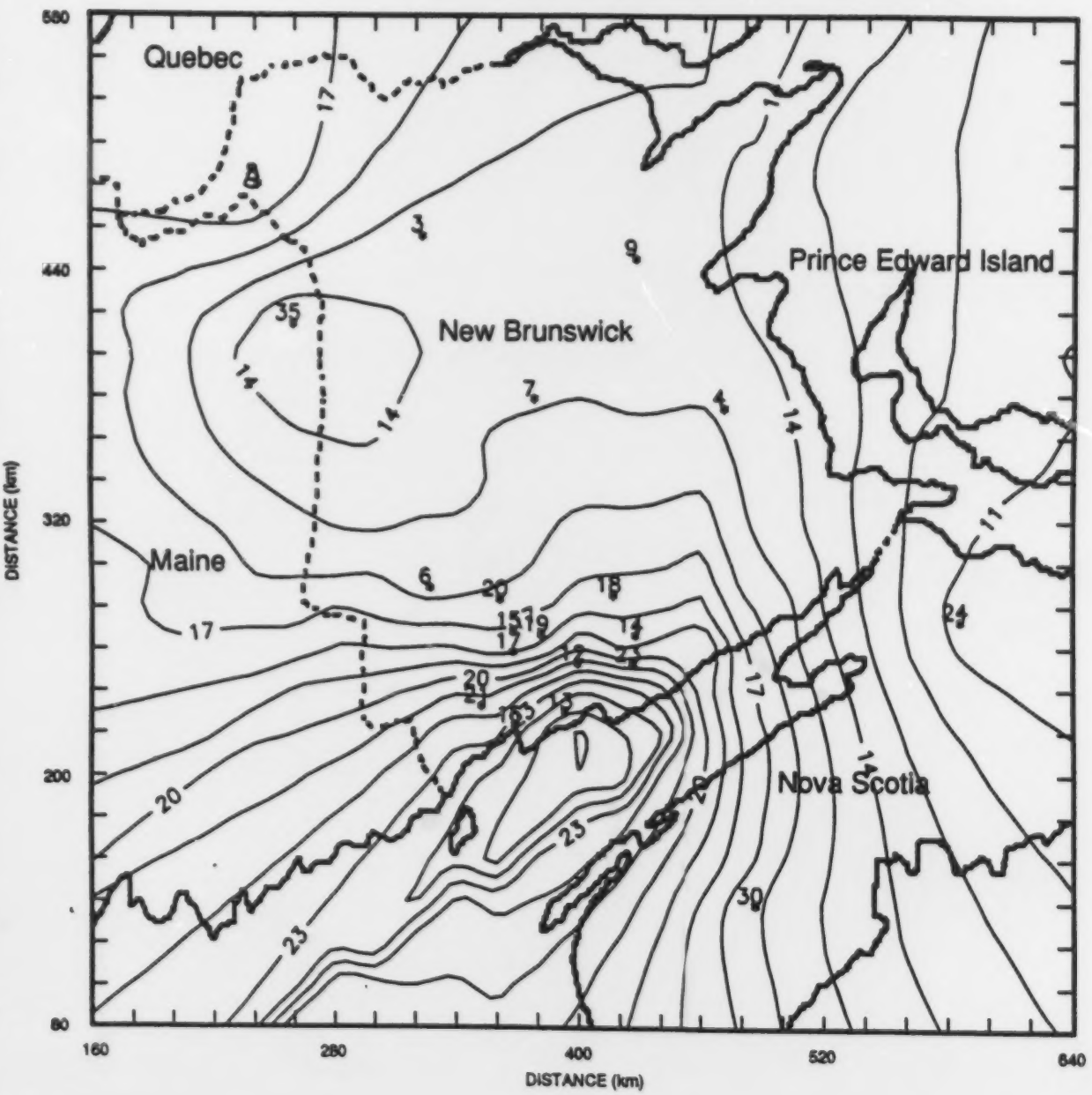
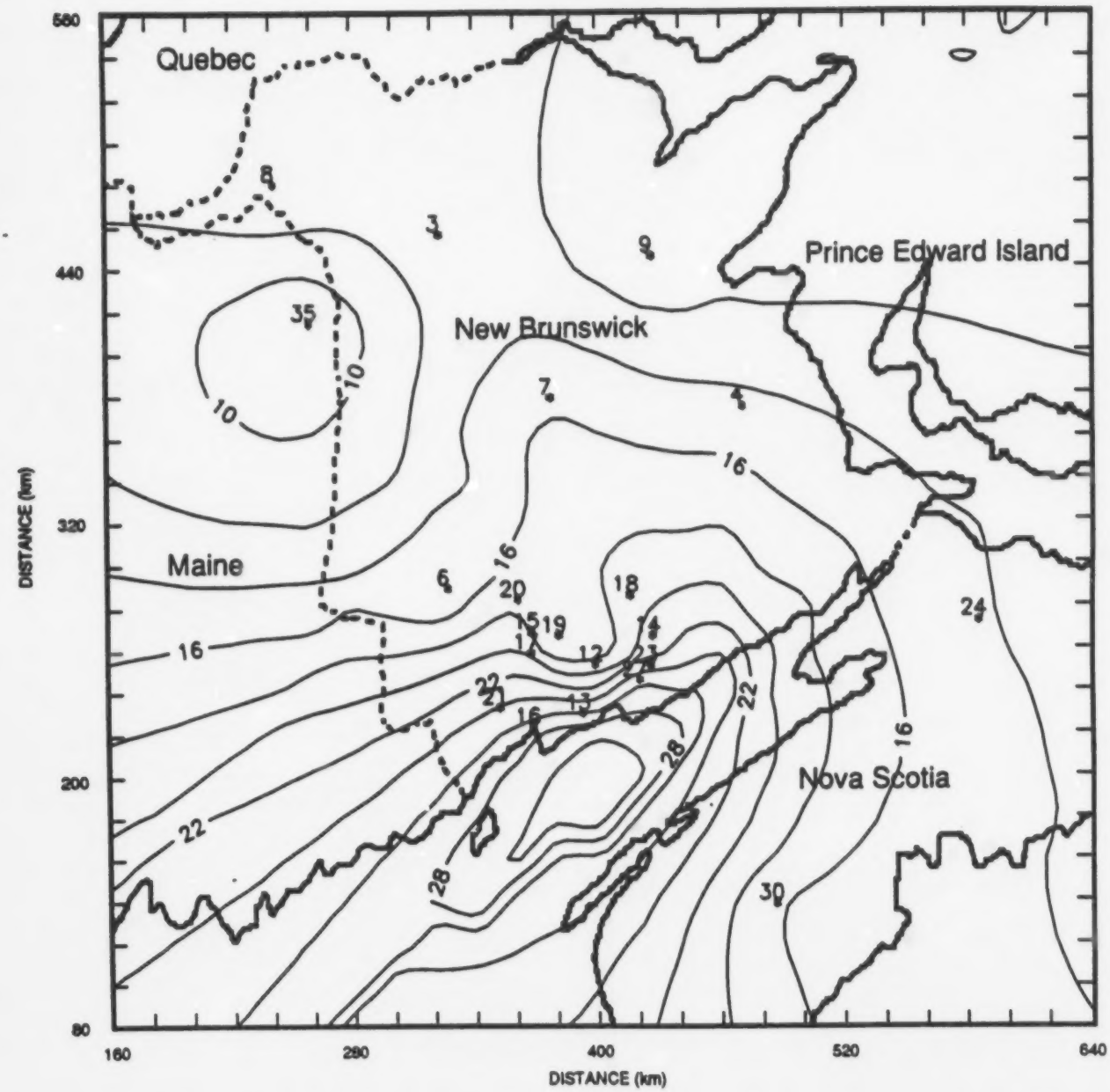


FIGURE 4-19

ANNUAL SULPHATE DEPOSITION (kg/ha) FOR YEAR 2
JUNE 1989 TO MAY 1990



that most of the weather patterns originate from the north, west and south rather from the east, the stations should provide representative indications of upper air meteorology.

There are five surface stations in New Brunswick (Charlo, Chatham, Fredericton, Moncton and Saint John) from which hourly precipitation data were available. The number of stations is limited and it should be noted that the Fredericton and Saint John surface stations are located near to most of the receptors which are in the Saint John area. In addition, this region has the highest precipitation amount and also has the highest gradients in annual precipitation (see Figures 4-20 and 4-21). Additional surface stations with hourly precipitation data would provide better spatial coverage.

Since wet deposition is determined to a large extent by precipitation, good spatial coverage of hourly precipitation stations is essential. Improvement in the number and spatial coverage of surface stations throughout the model domain would improve the reliability of model predictions. Use of daily observations of precipitation at wet deposition monitoring stations and at nearby meteorological stations (especially those which are used as alternate stations in the event that standard rain gauge measurements at the wet deposition site are unavailable) should be possible as follows. Data from the available hourly stations could be used to allocate the daily precipitation observations at the daily stations nearest to each hourly station. As a minimum, the daily rain gauge measurements at wet deposition monitoring stations should be compiled and used as model inputs.

Model input data for SO_2 emissions show that NB Power sources account for 79% of the total provincial emissions; this is higher than emissions inventory data for previous years when NB Power sources accounted for 55 to 70% of the provincial emissions (see Table 4-7 which lists SO_2 emissions from NB Power sources and for New Brunswick, Canada, the U.S. and eastern North America). The SO_2 emissions from NB Power and the Irving Oil Refinery sources input in the model

TABLE 4-7

Annual Sulphur Dioxide Emissions from NB Power and Selected Source Regions in Canada and the U.S. 1976 - 1990 (Thousands of tonnes)

GENERATING STATIONS	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Coleson Cove	17.5	46.9	46.2	50.4	54.5	36.3	44.1	23.5	24.8	21.2	22.7	36.6	58.4	74.0	58.5
Courtenay Bay	18.1	13.0	11.6	13.5	15.0	8.6	7.7	4.5	3.1	3.6	4.1	5.6	10.2	14.0	15.5
Dalhousie	1.4	1.1	3.1	2.1	20.0	45.1	45.7	52.1	52.3	43.3	44.1	45.9	61.1	60.3	45.8
Grand Lake	30.8	27.8	22.1	29.0	33.0	36.1	35.1	31.0	33.7	25.9	16.9	24.4	27.6	28.2	21.1
Chatham												0.7	0.6	0.4	0.2
TOTAL NB Power	67.8	90.8	85.0	95.0	122.5	126.1	132.6	111.1	113.7	94.0	87.8	115.2	157.9	176.9	141.1
New Brunswick[2]					220	221	206	172	162	136			203[3]	229[3]	
Canada[2]					4644	4291	3612	3625	3625	3704					
U.S.[2]					24448	24167	22552	22144	22610	20877					
Eastern North America[2]					24000	23300	21300	21100	21700	20200	19200	19900			

[1] NB Power, 1991
[2] Federal/Provincial Research and Monitoring Coordination Committee, 1990
[3] Annual Totals are for June 88/May 89 and June 89/May 90

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FIGURE 4-20

ANNUAL STANDARD RAIN GAUGE MEASUREMENTS (mm) FOR YEAR 1
JUNE 1988 TO MAY 1989

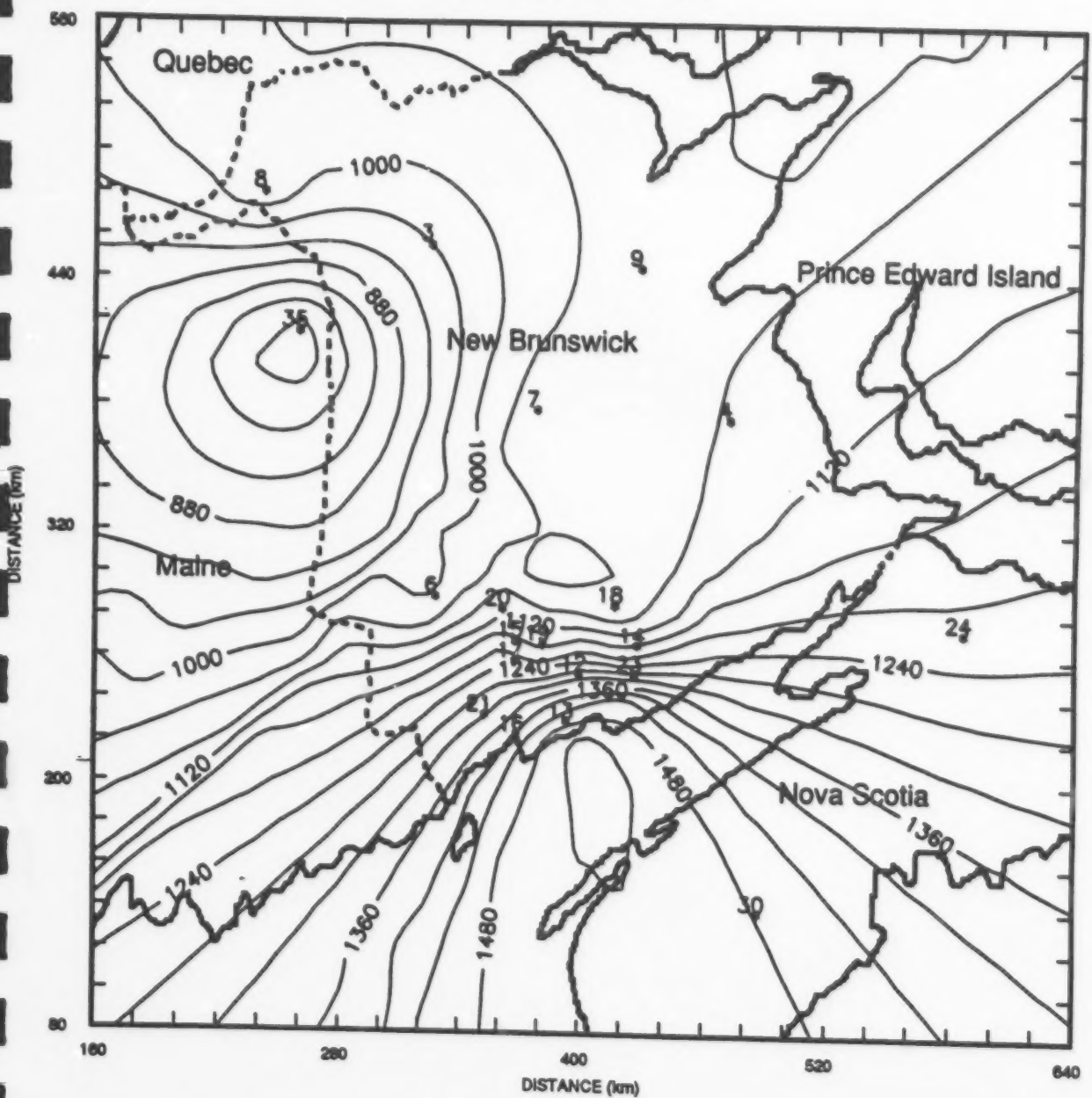
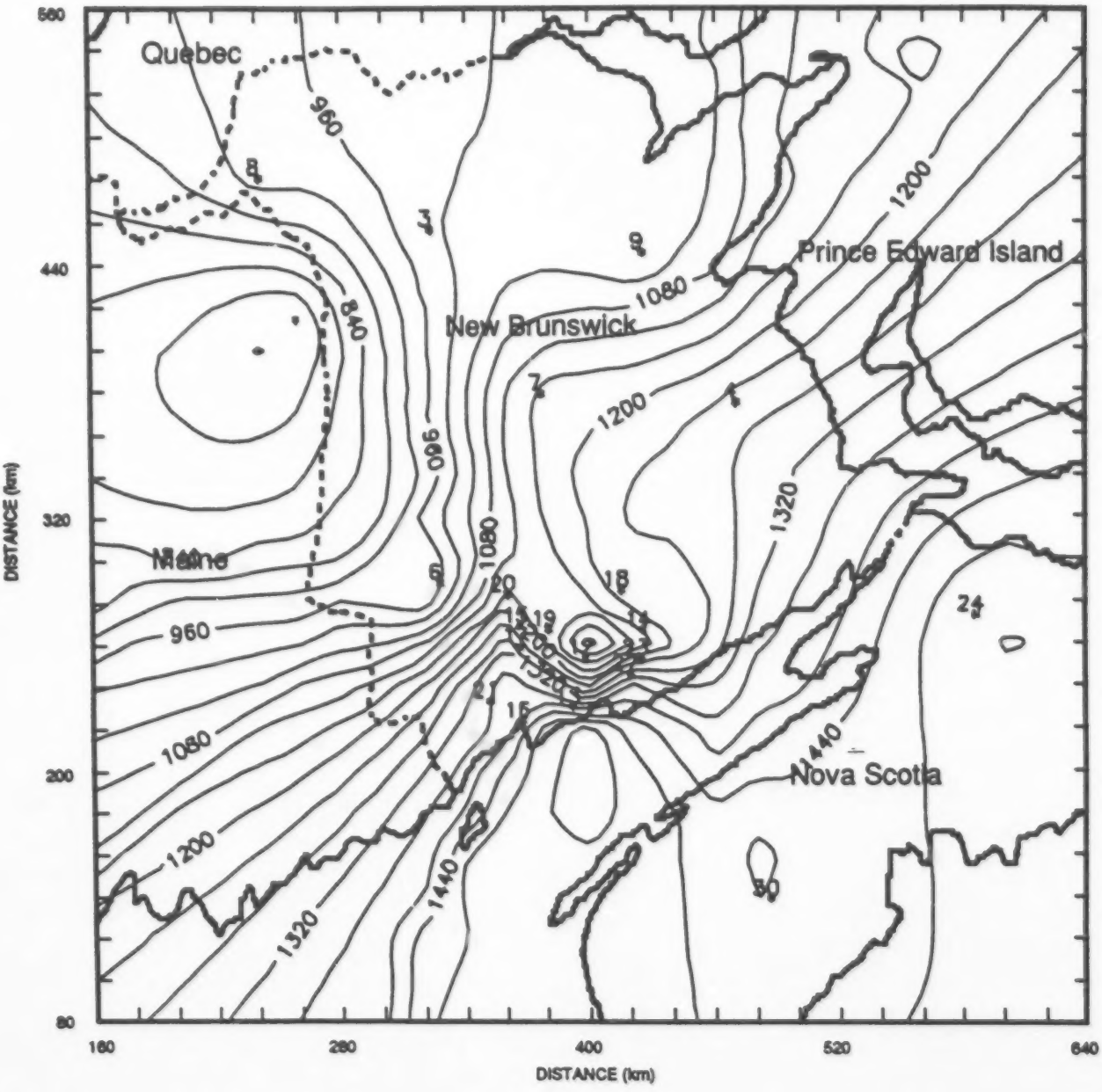


FIGURE 4-21

ANNUAL STANDARD RAIN GAUGE MEASUREMENTS (mm) FOR YEAR 2
JUNE 1989 TO MAY 1990



were provided on a monthly basis. Overall, the SO_2 emissions data are considered reliable since NB Power sources constitute such a large percentage of the total emissions. The SO_2 emissions from NB Power sources used in the model include the highest on record (see Table 4-7). In particular, emissions from the Coleson Cove TGS during the period modelled have included the highest to date. Model estimates for the Coleson Cove-Saint John area therefore represent the highest predictions for wet sulphur deposition as a result of Coleson Cove TGS emissions.

Also included in Table 4-7 are estimates of SO_2 emissions between 1980 and 1985 for the province of New Brunswick, Canada, the U.S. and eastern North America (defined as the region east of the Mississippi valley in the U.S. and east of the Saskatchewan-Manitoba border in Canada). The NB Power emissions account for 55-70% of the provincial SO_2 emissions between 1980 and 1985 and 79% in the years modelled (June 88/May 89 and June 89/May 90).

The provincial SO_2 emissions are negligible relative to eastern North America emissions. This comparison is relevant since the eastern North America area is frequently used as the model domain in large scale dispersion models, e.g. LERTAD, for estimating wet deposition. Sources in this region (eastern North America) are responsible for the long range transport of acidic pollutants (LRTAP) which accounts for the background wet S deposition in New Brunswick. The high background wet S deposition in New Brunswick is thus understandable given the relative magnitude of the emission sources in New Brunswick and eastern North America and the influence of LRTAP.

The comparison of model predictions with observations is dominated by the determination of the background wet deposition. The estimated annual background wet sulphur deposition levels were 5.11 and 5.26 kg S/ha/y for years 1 and 2 respectively. It should be noted that in previous studies, the background wet sulphate deposition has been estimated at 4.3 kg S/ha/y (12.9 kg SO_4/ha/y) based on the middle of the range of measurements at the Harcourt site which is

considered a regionally representative site (Davis et al., 1990; Davis and Lam, 1990; Washburn and Gillis, 1989). Since the predicted background deposition is in an acceptable range, it follows that the model predictions of the incremental deposition also are reasonable. The correlation of model predictions with observations is considered good bearing in mind the sparseness of the precipitation measurements that are available as model inputs. The importance of having additional hourly precipitation measurements is highlighted by the difference between correlations of weekly observations with measurements when all data are used as compared to when precipitation observations and model inputs are within 25% of each other.

It should be noted that the analysis conducted for this study examined only the wet sulphur deposition estimates. Model outputs also include SO_2 and $SO_4^{=}$ concentrations as well as dry and total deposition of each sulphur species. No attempt was made to compare model predictions with the (limited) ambient SO_2 concentration data that are available. Such comparisons (with data from monitoring stations at the Grand Bay monitoring station near Saint John and at Kejimkujic) are feasible since these locations were designated as receptors in the model runs.

Notwithstanding the limited precipitation data, the application of the model will provide reliable estimates of wet deposition in the Coleson Cove-Saint John area as well as throughout all areas of New Brunswick.

5 ACCOMPLISHMENTS AND RECOMMENDATIONS

5.1 PROJECT OBJECTIVES AND ACCOMPLISHMENTS

OBJECTIVES

The objectives of this model adaptation and application program were as follows:

1. to adapt and validate the LERTAD model for application in New Brunswick;

2. to determine the contribution of the Coleson Cove TGS to wet deposition in the Coleson Cove-Saint John area; and

3. to provide a reliable modelling tool that can be applied to predict wet deposition levels throughout the province.

ACCOMPLISHMENTS

- The mesoscale model MESOPUFF II, which is a component of the LERTAD system, has been successfully adapted and applied to a model domain which includes the entire province of New Brunswick. Model adaptation required computer systems related changes (hardware and system related) as well as extensive changes and additions to meteorological preprocessor programs in order to account for the changes in formats of meteorological data from both U.S. and Canadian sources. A scheme was developed to supplement missing hourly snowfall data by utilizing data from daily measurements and information available in the hourly records.

- Model predictions for a two year period were made and predictions were compared with monitoring data collected from the Coleson Cove and the Expanded New Brunswick Precipitation Monitoring Networks.

- The model was calibrated by assuming that the difference between observations and predictions represents the background and furthermore that this difference has to be adjusted to reflect the dependence of background wet deposition on the amount of precipitation. The adjusted background is considered reasonable when compared with monitoring data from remote sites in New Brunswick where minimal influence from New Brunswick sources is expected. Since the adjusted background is reasonable, it follows that the incremental deposition due to sources modelled do provide accurate estimates of wet deposition. A summary of the model performance is given below.

MODEL PERFORMANCE

The performance of the model was evaluated by comparison of observed and predicted wet sulphur deposition and by examining the relationship between weekly and seasonal predictions and observations. The correlation coefficients obtained between seasonal observations and predictions (including the derived background) are very good for 7 of 8 seasons as evidenced by correlation coefficients (R) that are greater than 0.44 for 7 of 8 seasons when all receptors are considered. For receptors in the Coleson Cove-Saint John area, the correlations are generally better with all 8 seasons having R values greater than 0.48. Comparison of observations and predictions on a weekly basis are also good especially for cases where the precipitation measured at wet deposition monitoring stations and at hourly meteorological stations are within 25% of each other. This emphasises the importance of obtaining extensive and consistent hourly precipitation data for model inputs.

SUMMARY OF RESULTS

The main results of the study are as follows:

- The Coleson Cove TGS is predicted to contribute an average of 8.6% to wet sulphur deposition at all receptors and an average of 12.5% to wet deposition at receptors in the Coleson Cove-Saint John area.

- Background wet sulphur deposition, that is due to all sources other than those modelled, accounts for an average of 81% to the annual wet sulphur deposition in the Coleson Cove-Saint John area. For all receptors (monitoring stations) throughout the model domain, the background is predicted to contribute an average of 85% to wet sulphur deposition.

- The model estimates showed that the Coleson Cove source contributed between 49 and 76% to the **incremental** wet sulphur deposition (i.e., excluding the background).

5.2 RECOMMENDATIONS

The study objectives included the provision of a modelling tool that would be applied to predict wet deposition levels in New Brunswick. Such predictions are becoming increasingly important as sulphur dioxide emission reduction programs (Federal, provincial and in the U.S.) are implemented. The emissions reductions programs will be effected by several means including switching to lower sulphur fuels, retrofitting of flue gas desulphurization and wide range of demand side management initiatives that would result in lower demand for electricity. The effects of these measures on emissions and thus ambient SO_2 concentrations and wet deposition will need to be determined through monitoring or modelling. Monitoring programs are time consuming and expensive if reliable and extensive spatial coverage is required. The availability of a reliable dispersion model

provides a relatively inexpensive means of predicting the impacts of changes in SO_2 emissions on ambient SO_2 concentrations and wet sulphur deposition. The model predictions will allow such determinations to be made anywhere in the province where sources are located or where predictions are required.

The recommendations listed below indicate suggested improvements to the model inputs and describe how the model should be applied in the context of the New Brunswick SO_2 emissions reduction program.

I) **Improvements in Model Inputs and Analysis**

The reliability of the model predictions will be improved by use of the most current emissions information. The emissions data are continually being updated and before any additional model runs are performed, the most recent stack information should be obtained. This effort should be restricted to New Brunswick sources since the out of province sources modelled (i.e., within the model domain) contribute little to predicted wet deposition.

The hourly precipitation data required as input to the model can be improved by compiling historical daily precipitation measurements at all wet deposition monitoring stations and using this information to complement model inputs. (Details for doing this were described in the text).

The model assessment should be extended to the comparison of ambient SO_2 concentrations even though there is a limited number of monitoring stations with which model predictions can be compared.

II) Application to New Brunswick

The following strategy is recommended in order to apply the model to New Brunswick in general and to NB Power needs in particular.

a) Scope and objectives of model application

The species modelled should be expanded to include nitrogen species (wet nitrate and nitric acid, and particulate nitrate and gaseous nitrogen dioxide and nitric acid concentrations). Emissions data for nitrogen oxides need to be compiled. It is expected that the completeness and reliability of the NOx emissions will not be as great as for sulphur dioxide.

The objectives of future model applications include the following:

- Determination of incremental impacts of NB Power sources
- Assistance in siting of wet deposition monitoring stations and rationalization of the reduction in the number of wet deposition monitoring stations
- Determination of the impacts of NOx emissions on nitrate deposition and to provide indication of the ambient NO_2 levels. The latter may be useful in helping to estimate NO_x levels in rural areas and thus help in determining impacts of NOx on ozone formation.

b) Grouping of sources

The following grouping of sources is recommended:

* Isolate NB Power sources into up to three source groups, namely:
  1 Coleson Cove and Courtenay Bay
  2 Chatham Millbank, Grand Lake
  2 Belledune, Dalhousie TGS
* Group the remainder of sources as previously modelled into three source groups (NB south, NB north, and out of province)

c) Time period for modelling

The second year (June 1989 to May 1990) should be selected as the "base" year to be modelled since this would provide the most conservative wet deposition estimates. Meteorological data for this year would be used in simulations as will be described below. It should be noted that the derived background must be based only on sources that existed in the period. On the other hand if better emissions data for existing sources is available then the background may be redetermined as was done in this study using only existing sources.

d) Strategy for modelling

It is expected that NB Power will require modelling of scenarios ranging from additional capacity (emissions) at existing or new stations to impacts of load shifting during selected periods (seasons or time of day). Such modelling can be economically done by modelling only the various emissions scenarios for the NB Power source groups and adding to the remaining source groups. (This will require a one-time modelling of the

remaining source groups). The modelling of NB Power sources can be done for any desired time period (1 week to 1 year).

In the case of new sources (e.g., Belledune TGS) or where there are changes to existing sources (e.g., Dalhousie or Grand Lake), additional receptors such as at any new wet deposition monitoring stations established in the vicinity of these sources, should be modelled. Also, additional receptors collocated with the hourly precipitation meteorological stations should be added.

The additional receptors (expected to be of the order of 5 to 10 additional sites) should not impose undue resource requirements to run the model.

e) Since completing the model runs, additional reductions in execution time have been realised by using a 80486 computer with an 80486 compiler. Model runs which previously took 3 days have been reduced to less than 1 day. Such runs involved up to 16 sources, and 30 receptors for one season of simulation. Simulations of NB Power sources alone are expected to require execution times of 3-6 hours per season for about 30 receptors. These model execution times are acceptable and are inexpensive. Data analysis effort will remain unchanged but would depend on the detail required. For example analysis of hourly NO_2 or SO_2 concentration data represents a greater level of detail than was undertaken in this study.

III) Benefits of the Modelling and Monitoring Programs

The monitoring and model adaptation program undertaken over the past three and a half years have provided NB Power and the Province of New Brunswick with accurate and reliable monitoring data on wet deposition levels and a reliable tool for predicting future wet deposition levels in the

province. The question of the contribution of local sources especially NB Power sources to wet sulphur deposition has been answered. Future changes in wet deposition to reductions in SO_2 emissions from NB Power and other sources in the province now can be reliably predicted. This capability is important given the ongoing sulphur dioxide emissions reduction program and also the imminent NOx/VOC management plan that will require knowledge of the impact of NOx emissions. These impacts of NOx emissions are not limited to photochemical oxidant pollutants but require assessment of acid rain impacts.

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APPENDIX 1

APPENDIX 1 - CHANGES TO THE MESOPUFF II MODELLING SYSTEM

A1.1 OVERVIEW OF MODELLING SYSTEM

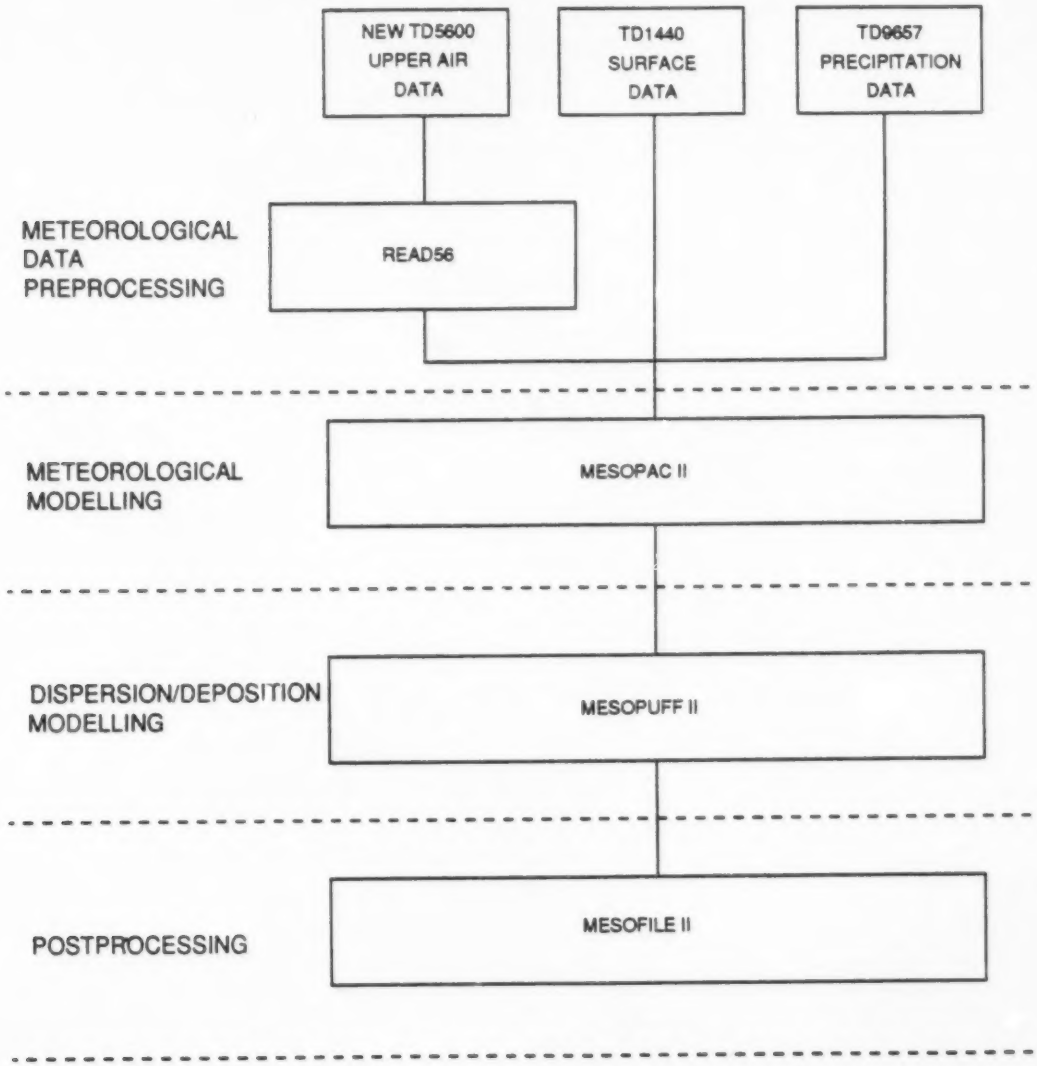
The MESOPUFF II modelling package consists of a set of programs designed for the simulation of mesoscale transport, chemical transformation, and wet and dry removal of sulphur dioxide (SO_2), sulphate ($SO_4^=$), nitrogen oxides (NO_x), nitric acid (HNO_3) and nitrate (NO_3^-) (Scire et al., 1984). As shown in Figure A1-1, the MESOPUFF II dispersion model is a modelling system which includes a meteorological model, MESOPAC II, with its associated meteorological data preprocessor, READ56, and a postprocessing program, MESOFILE II. Standard formatted meteorological data files routinely archived by the National Climatic Centre (NCC) are required to drive the meteorological model. In this section, the changes made to the MESOPUFF II modelling package are described.

READ56 reads and processes the twice-daily upper air wind and temperature sounding data in U.S. TD5600 format and extracts the fields of pressure, height, temperature, wind speed and wind direction for each sounding level up to the uppermost pressure level specified by the user. At the same time, it scans through the data for missing, invalid, or suspicious data. Warning messages are subsequently printed to flag missing or incomplete soundings in the output file, which then needs to be edited by the user to eliminate all warning messages. The completely edited output file is then suitable for input to the meteorological model, MESOPAC II.

MESOPAC II reads the upper air data files created by READ56 and hourly surface meteorological data in U.S. TD1440 format and precipitation data in U.S. TD9657 format, and creates time and space interpolated fields of meteorological variables. MESOPAC II generates hourly gridded fields in two vertical layers: (1) lower layer winds to represent transport within the boundary layer, and (2) upper layer winds to represent flow above the boundary layer. In addition, hourly values of the PGT

FIGURE A1-1

MAJOR COMPONENTS OF THE MESOPUFF II MODELLING SYSTEM



stability class, surface friction velocity, Monin-Obukhov length, convective velocity scale, and mixing height are computed at each grid point.

MESOPUFF II is a Lagrangian, variable trajectory, Gaussian puff superposition model. It is designed to account for the spatial and temporal variations in the transport, diffusion, chemical transformation, and removal mechanisms encountered on regional scales. MESOPUFF II is driven by the gridded meteorological fields generated by the MESOPAC II meteorological model. With the puff superposition approach, a continuous plume is modelled as a series of discrete puffs. Each puff is transported independently of other puffs and is subject to growth by diffusion, chemical conversion, wet removal by precipitation scavenging, and dry deposition at the surface. The time integrated contribution of each puff is summed to determine the total concentration and deposition fluxes at gridded and discrete receptors.

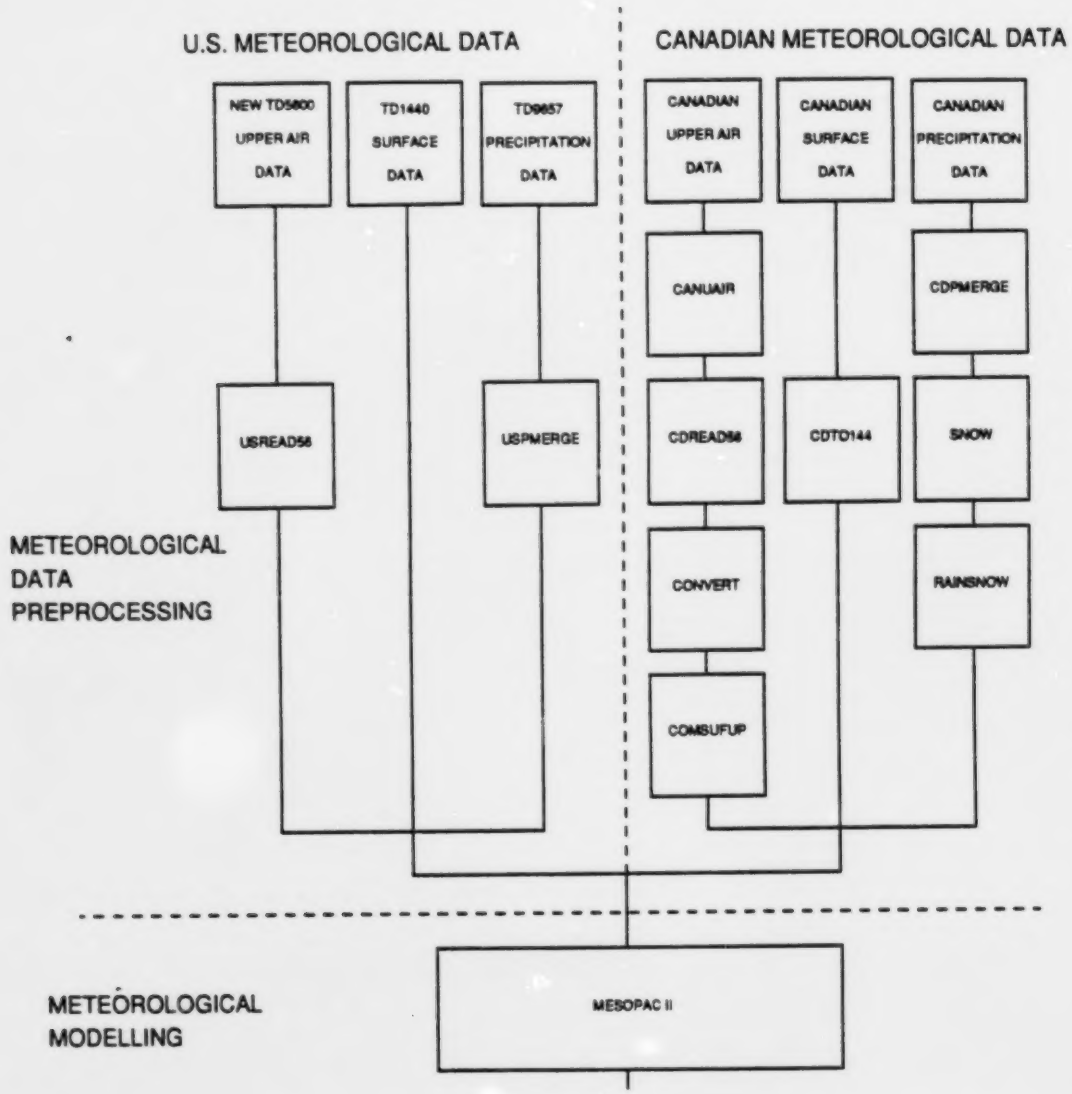
The postprocessing program, MESOFILE II, provide options for additional analysis of the model output, including time averaging, line printer contour plots, statistical analysis of the gridded or non-gridded receptor concentrations, and wet and dry pollutant fluxes.

A1.2 SYSTEM MODIFICATIONS AND ADDITIONS

Some modifications and additions were made to MESOPUFF II modelling package to increase its flexibility and to expand its capabilities for accepting the currently available data formats for U.S. and Canadian meteorological data. Since the meteorological data included both the U.S. and Canadian data formats, some preprocessing programs were added and also the meteorological data preprocessor was modified to generate data in format compatible with the MESOPAC II model. Figure A1-2 shows the major components of the modified version of the meteorological preprocessors for both the U.S. and Canadian data. The following sections describe the modifications and additions made to the modelling system.

FIGURE A1-2

MAJOR COMPONENTS OF THE MODIFIED VERSION OF THE METEOROLOGICAL DATA PREPROCESSORS FOR MESOPUFF II



A1.2.1 PREPROCESSING OF U.S. METEOROLOGICAL DATA

The upper air data obtained from NCC is in TD5600 format. The format of data received were not compatible with READ56 because NCC has recently made changes to this TD5600 format. READ56 was thus modified into USEREAD56 to accept this new TD5600 format.

For the precipitation data, the TD9657 format is no longer available from NCC. The data are currently obtained in TD3240 format which is a non-hourly data format. The program PMERGE, extracted from CALPUFF[1], was be used to convert TD3240 data to hourly data format. However, the format of the output file generated by PMERGE is not compatible with MESOPUFF II; therefore, PMERGE was modified into USPMERGE to produce hourly precipitation data file in the format compatible with MESOPAC II. The modified PMERGE was added to the MESOPUFF II modelling system to accept the TD3240 precipitation data format.

A1.2.2 PREPROCESSING OF CANADIAN METEOROLOGICAL DATA

The Canadian meteorological data available from AES are in formats which are different from those required by MESOPUFF II. The AES data were converted to the format which READ56 and eventually MESOPAC II can accept.

The programs, CANUAIR, CONVERT and COMSUFUP, were written and also READ56 was modified for the conversion and preprocessing of the Canadian upper air data. CANUAIR rearranges the raw upper air data to the same layout as the U.S. TD5600 format. The codings in the Canadian data are different from the U.S. data, thus READ56 was modified into CDREAD56 to accept the Canadian codings. Since measurements of wind speed and wind direction are available only for pressure sounding levels of 900, 850, 800 and 700 mb at the Canadian

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1 CALPUFF is an air dispersion model, which can take NCC's precipitation data in TD3240 format to generate hourly precipitation data, written and provided by Joseph S. Scire, Principal Meteorologist, Sigma Research Corporation, Massachussetts, U.S.A.

stations, the program CONVERT extracts these sounding levels and the program COMSUFUP adds a surface level sounding. MESOPAC II requires the upper air data file to contain the surface level at pressure (about 1,000 mb). In order to incorporate this surface level into the upper air data file, COMSUFUP extracts the fields of pressure, height, temperature, wind direction and wind speed from the hourly surface data file for the corresponding station and combines it with the output data file from CONVERT to generate an upper air data file which is compatible with the MESOPAC II model.

The program CDTO144, was written to convert the Canadian surface meteorological data to the U.S. TD1440 format.

The program PMERGE was modified into CDPMERGE, to convert the Canadian precipitation data into the U.S. TD9657 format. Hourly precipitation data for Canadian stations include only rainfall observations but snowfall is recorded only on a daily basis. Therefore, in order to include hourly snowfall data in winter seasons, the programs SNOW and RAINSNOW, were written to allocate the water equivalent amount of daily snowfall to those hours coded of having snow in the hourly surface meteorological data file and missing precipitation amount information.

A1.2.3 CHANGES TO MESOPUFF

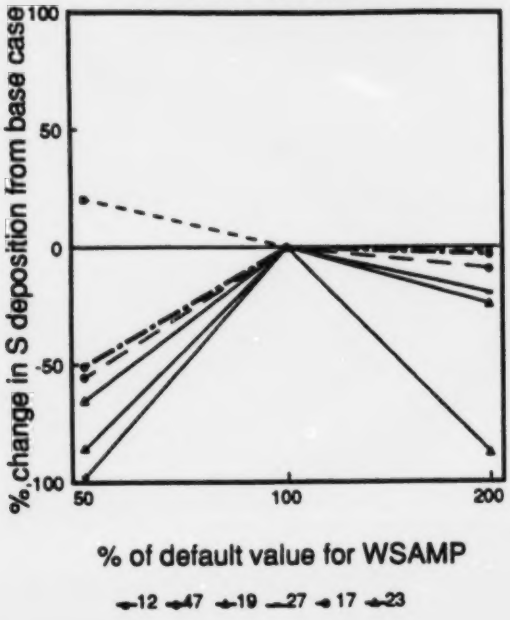
The MESOPUFF II model has a limit on the number of sources that can be modelled because it can only handle 500 puffs (from all sources modelled) at a time . Therefore, in order to increase the number of sources that can be modelled in each run, the MESOPUFF II model was modified to handle 5,000 puffs at a time. This decreased significantly the number of source groups and thus model runs. Otherwise, the sources would have to be divided into a larger number of source groups with fewer sources in each group.

APPENDIX 2

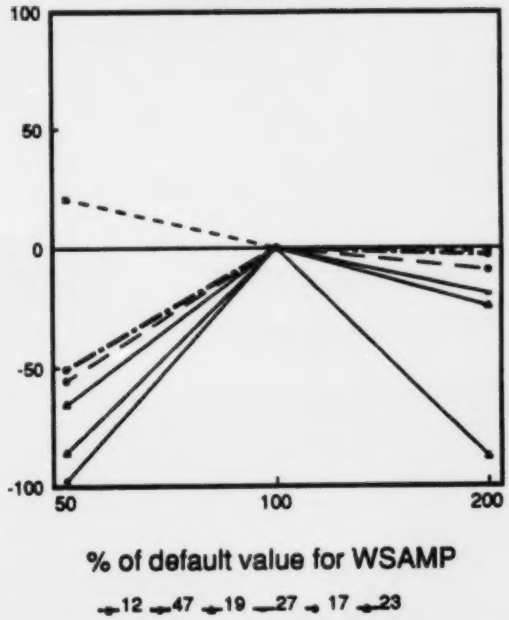
APPENDIX 2.1A

TIER 1 SENSITIVITY RUNS

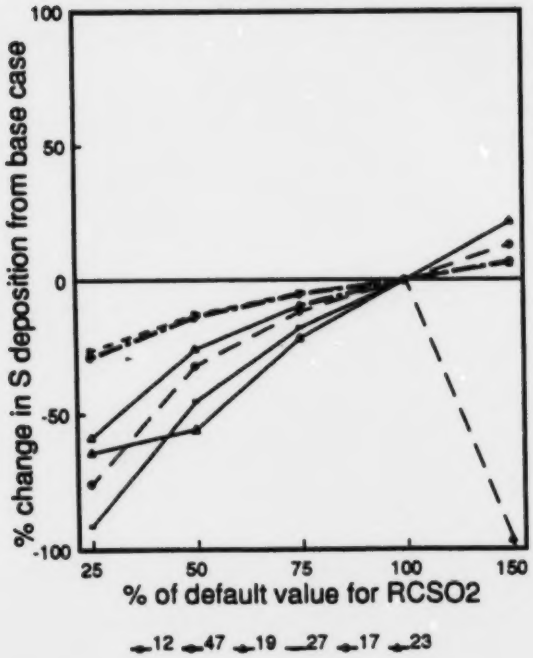
VARIABLE: NSAMAD



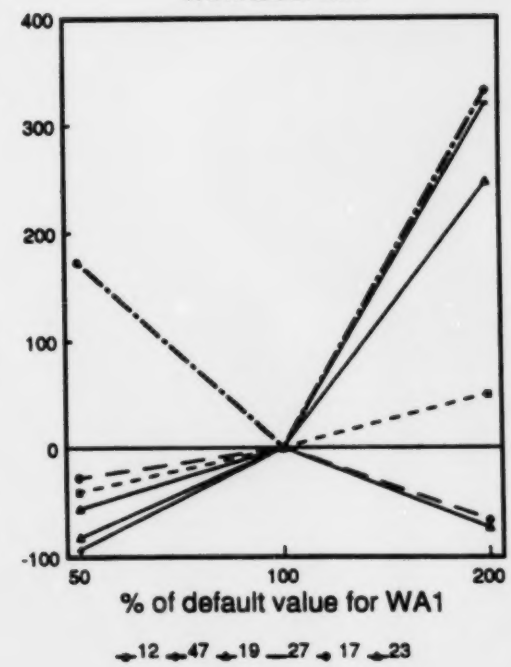
VARIABLE: WSAMP



VARIABLE: RCSO2



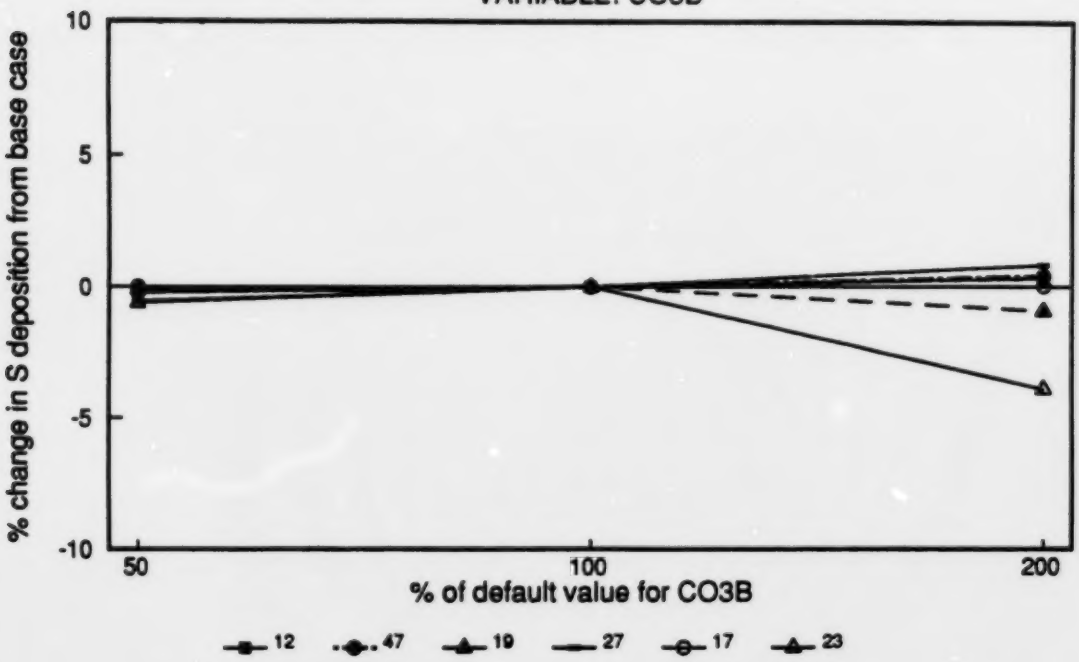
VARIABLE: WA1



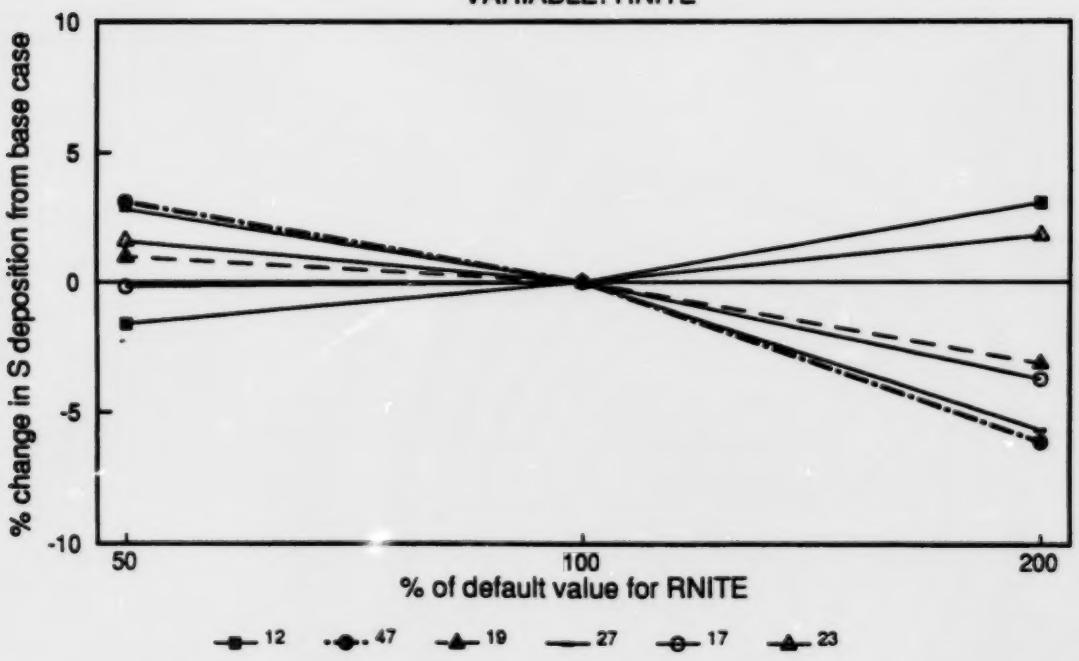
APPENDIX 2.1B

TIER 1 SENSITIVITY RUNS

VARIABLE: CO3B



VARIABLE: RNITE



APPENDIX 2.2

SUMMARY OF TIER 1 SENSITIVITY RUNS (*) FOR SELECTED MESOPUFF VARIABLES

Receptor	Base Case	% Of Base Case: NSAMAD			% Of Base Case: WSAMP				% Of Base Case: AGEMIN			% Of Base Case: RCSO2				
		50	100	200	Base Case	50	100	200	50	100	200	25	50	75	100	150
	kg S/ha/y	% change from base case			kg S/ha/y	% change from base case			% change from base case			% change from base case				
12	0.13	2	0	-11	0.13	21	0	-2	0	0	0	-26	-13	-5	0	6
47	0.14	43	0	-74	0.14	-51	0	-3	0	0	0	-29	-14	-5	0	7
19	0.09	-89	0	-37	0.09	-65	0	-88	0	0	0	-59	-26	-10	0	-96
27	0.17	2	0	-46	0.17	-98	0	-20	0	0	0	-91	-45	-18	0	21
17	0.25	0	0	-46	0.25	-55	0	-9	0	0	0	-76	-32	-12	0	13
23	0.20	66	0	-56	0.20	-86	0	-25	0	0	0	-64	-56	-22	0	21
15	2.83	0	0	6	2.83	8	0	-7	0	0	0	-9	-4	-1	0	1
14	0.86	-16	0	-3	0.86	-2	0	-4	0	0	0	-25	-12	-5	0	6
6	2.45	0	0	6	2.45	7	0	-7	0	0	0	-15	-7	-2	0	3
4	0.57	-5	0	7	0.57	16	0	-1	0	0	0	-43	-23	-10	0	13
18	0.04	123	0	-11	0.04	56	0	-22	0	0	0	17	131	-49	0	62
7	0.02	74	0	-29	0.02	13	0	-3	0	0	0	-45	-25	-11	0	15
8	0.02	39	0	-12	0.02	10	0	-17	0	0	0	-61	-35	-15	0	22
44	0.02	407	0	523	0.02	343	0	513	0	0	0	58	346	502	0	121
24	0.02	-19	0	11	0.02	-49	0	-28	0	0	0	-57	3	-25	0	-33
13	0.02	-42	0	-9	0.02	-1	0	-2	0	0	0	-32	-16	-6	0	8
45	0.02	435	0	103	0.02	59	0	-33	0	0	0	213	387	544	0	80
30	0.01	17	0	-18	0.01	5	0	17	0	0	0	137	450	632	0	151
9	0.01	37	0	-22	0.01	13	0	0	0	0	0	-47	-27	-12	0	17
3	0.01	236	0	0	0.01	15	0	-2	0	0	0	-61	-35	-15	0	22
26	0.00	66	0	-71	0.00	41	0	-71	0	0	0	-63	-82	-25	0	111
20	0.00	940	0	847	0.00	403	0	178	0	0	0	239	715	950	0	160
35	0.00	124	0	-29	0.00	46	0	-50	0	0	0	-92	-82	-49	0	-95
46	0.00	-36	0	148	0.00	101	0	63	0	0	0	-31	8	23	0	32
43	0.00	46	0	112	0.00	136	0	-64	0	0	0	-25	166	-44	0	131
41	0.00	64	0	178	0.00	374	0	457	0	0	0	24	481	315	0	310
42	0.00	499	0	-50	0.00	-12	0	-64	0	0	0	-54	-35	-38	0	-52
25	0.00	1285	0	-22	0.00	19	0	-10	0	0	0	-29	1	10	0	31
25	0.00	1383	0	-19	0.00	22	0	-5	0	0	0	-26	4	12	0	32
21	0.00	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0	0
16	0.00	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0	0

* A 1 week period starting Julian day 166 in 1988 modelled, all source groups

APPENDIX 2.2 (Cont'd)

SUMMARY OF TIER 1 SENSITIVITY RUNS (*) FOR SELECTED MESOPUFF VARIABLES

Receptor	Base Case	% Of Base Case: WA1			% Of Base Case: CO3B			% Of Base Case: RNITE		
		50	100	200	50	100	200	50	100	200
	kg S/ha/y	% change from base case			% change from base case			% change from base case		
12	0.13	-40	0	50	0	0	0	-2	0	3
47	0.14	173	0	331	0	0	0	3	0	-6
19	0.09	-56	0	-73	0	0	-1	1	0	-3
27	0.17	-94	0	319	-1	0	1	3	0	-6
17	0.25	-27	0	-66	0	0	0	0	0	-4
23	0.20	-82	0	246	-1	0	-4	2	0	2
15	2.83	-40	0	44	0	0	0	0	0	1
14	0.86	-38	0	43	0	0	0	-1	0	3
6	2.45	-46	0	72	0	0	0	0	0	1
4	0.57	-19	0	12	-1	0	2	-1	0	1
18	0.04	43	0	16	-4	0	6	14	0	-6
7	0.02	-25	0	22	-1	0	2	-1	0	2
8	0.02	-11	0	-1	-1	0	2	-1	0	2
44	0.02	489	0	982	-3	0	5	5	0	529
24	0.02	-65	0	-46	-4	0	-59	2	0	-68
13	0.02	-40	0	45	0	0	0	-1	0	3
45	0.02	362	0	147	-15	0	-42	-6	0	-53
30	0.01	366	0	244	-22	0	-40	-9	0	-58
9	0.01	-21	0	14	-1	0	2	-1	0	1
3	0.01	-5	0	-9	-1	0	2	-1	0	2
26	0.00	-51	0	18	-11	0	-22	-9	0	-21
20	0.00	351	0	499	-1	0	2	-33	0	-22
35	0.00	-40	0	-24	-3	0	-10	-2	0	-10
46	0.00	110	0	54	-8	0	13	-6	0	13
43	0.00	55	0	52	-15	0	25	-12	0	24
41	0.00	186	0	519	-36	0	466	-28	0	463
42	0.00	-54	0	-35	-4	0	-48	-5	0	-45
25	0.00	58	0	-60	-2	0	4	0	0	0
25	0.00	63	0	-63	-2	0	4	0	0	0
21	0.00	0	0	0	0	0	0	0	0	0
16	0.00	0	0	0	0	0	0	0	0	0

* A 1 week period starting Julian day 166 in 1988 modelled, all source groups

APPENDIX 3

APPENDIX 3A

Individual Stack Parameter Data for MESOPUFF II Runs

Source description	SOURCE GROUP	X-grid	Y-grid	HTSTAK (m) stack ht	D (m) stack dia	W (m/s) exit vel	TSTAK (°K) temp
St. Anne-Nackawic Pulp Co. Ltd.	C	15.89	15.91	52.1	3.96	13.60	422
Fraser Inc., Edmundston	C	11.57	23.35	58.2	2.40	7.70	343
Fraser Inc., Edmundston	C	11.57	23.35	61.0	2.70	8.10	468
Fraser Inc., Edmundston	C	11.57	23.35	26.8	0.18	31.05	341
Fraser Inc., Edmundston	C	11.56	23.35	28.7	0.71	19.12	314
Atholville Pulp	C	17.54	26.93	65.2	1.37	7.90	347
Atholville Pulp	C	17.54	26.93	44.5	0.25	10.60	325
Atholville Pulp	C	17.54	26.93	44.5	0.25	4.30	339
Atholville Pulp	C	17.54	26.93	34.2	0.61	28.80	315
NB Power - Dalhousie	C	18.92	27.30	84.0	3.00	18.50	433
NB Power - Dalhousie	C	18.92	27.30	168.0	3.90	24.00	444
NBIP	C	18.82	27.39	38.1	2.59	9.20	408
BMS Smelter	C	21.07	26.48	68.6	2.29	11.20	343
BMS Smelter	C	21.07	26.48	39.6	3.05	21.60	328
BMS Smelter	C	21.07	26.48	39.6	3.96	17.70	333
NB Power - Chatham	B	22.49	21.63	76.0	3.00	7.00	443
Miramichi Pulp & Paper Ind.	B	21.99	21.28	65.5	3.05	12.30	444
Miramichi Pulp & Paper Ind.	B	21.99	21.28	32.8	2.14	12.02	491
Miramichi Pulp & Paper Ind.	B	21.99	21.28	18.3	1.52	10.10	424
Miramichi Pulp & Paper Ind.	B	21.99	21.28	67.8	2.03	11.50	475
NB Power - Coleson Cove	A	19.98	11.21	183.0	4.90	30.50	423
NB Power - Courtenay Bay	B	20.75	11.88	107.0	3.70	12.50	423
NB Power - Grand Lake	B	20.59	16.33	76.0	3.80	9.00	463
Consolidated Bathurst (Pulp mill)	C	21.69	24.80	33.0	0.20	10.00	400
Utopia - pulp mill	B	17.90	11.05	12.9	2.50	10.00	400
Rothesay Paper	B	20.14	12.50	50.3	2.70	10.00	563
Lantic Sugar	B	20.60	11.86	48.0	2.70	0.70	523
St. John Regional Hospital	B	20.48	12.09	64.0	0.40	1.40	473
Irving Pulp and Paper (Fuel)	B	20.44	11.83	90.0	4.40	13.20	458
Irving Refinery	B	20.66	11.95	60.0	0.90	15.00	644
Irving Refinery	B	20.66	11.95	60.0	0.90	15.00	644
Irving Refinery	B	20.66	11.95	73.0	2.70	7.70	505
Irving Refinery	B	20.66	11.95	73.0	2.70	7.70	505
Irving Refinery	B	20.66	11.95	22.8	2.10	14.90	444
Irving Refinery	B	20.66	11.95	39.6	2.40	5.60	672
Irving Refinery	B	20.66	11.95	55.9	1.20	10.40	588
Irving Refinery	B	20.66	11.95	15.2	1.40	19.80	644
Irving Refinery	B	20.66	11.95	30.4	1.70	10.60	1244
FlakeBoard	B	15.73	11.37	17.3	0.66	10.00	470
FlakeBoard	B	15.73	11.37	11.1	0.39	10.00	482
NS Power - Maccan GS	D	27.47	14.23	38.0	2.83	30.50	455
NS Power - Trenton GS	D	33.90	13.57	91.4	3.20	30.50	419
Texaco Canada Inc	D	30.86	8.11	31.0	1.22	5.00	511
Texaco Canada Inc	D	30.86	8.11	31.0	1.22	5.00	511
Texaco Canada Inc	D	30.86	8.11	44.0	1.45	5.00	593
Texaco Canada Inc	D	30.86	8.11	49.0	0.77	13.00	863
Texaco Canada Inc	D	30.86	8.11	49.0	0.77	13.00	863
Texaco Canada Inc	D	30.86	8.11	30.0	0.76	13.00	863
NS Power - Tufts Cove GS	D	30.47	8.40	152.0	3.05	30.50	432
NS Power - Tufts Cove GS	D	30.47	8.40	152.0	3.05	30.50	432

APPENDIX 3A (Cont'd)

Individual Stack Parameter Data for MESOPUFF II Runs

Source description	SOURCE GROUP	X-grid	Y-grid	HTSTAK (m) stack ht	D (m) stack dia	W (m/s) exit vel	TSTAK (°K) temp
NS Power - Tufts Cove GS	D	30.47	8.40	152.0	3.05	30.50	432
NS Power - Point Tupper GS	D	38.87	13.68	107.0	3.35	30.50	422
Consol-Barthust, Dev Chaleurs	D	20.82	27.97	49.0	2.70	10.00	410
Consol-Barthust, Dev Chaleurs	D	20.82	27.97	43.0	1.20	10.00	383
Consol-Barthust, Dev Chaleurs	D	20.82	27.97	30.0	1.20	10.00	338
Consol-Barthust, Dev Chaleurs	D	20.82	27.97	37.0	0.80	10.00	338
La Compagnie Gaspesia Ltee	D	25.06	28.87	69.0	3.20	10.00	539
La Compagnie Gaspesia Ltee	D	25.06	28.87	69.0	3.20	10.00	486
La Compagnie Gaspesia Ltee	D	25.06	28.87	37.0	0.30	10.00	313
La Compagnie Gaspesia Ltee	D	25.06	28.87	35.0	2.40	10.00	373
F.F. Soucy Inc	D	7.18	25.93	38.0	1.68	10.00	456
F.F. Soucy Inc	D	7.18	25.93	38.0	1.68	10.00	456
Soc Canadienne De Metaux Reynolds Lt	D	12.14	33.83	51.0	2.80	10.00	356
Soc Canadienne De Metaux Reynolds Lt	D	12.14	33.83	70.0	4.29	10.00	356
Soc Canadienne De Metaux Reynolds Lt	D	12.14	33.83	70.0	4.29	10.00	356
Soc Canadienne De Metaux Reynolds Lt	D	12.14	33.83	50.0	2.80	10.00	356
Soc Canadienne De Metaux Reynolds Lt	D	12.14	33.83	50.0	2.80	10.00	356
Millinocket	D	10.21	13.78	106.1	5.49	13.11	438
Millinocket	D	10.21	13.78	106.1	5.49	13.11	438
Millinocket	D	10.21	13.78	106.1	5.49	13.11	438
Millinocket	D	10.21	13.78	106.1	5.49	13.11	438
Millinocket	D	10.21	13.78	103.0	2.44	18.29	348
Millinocket	D	10.21	13.78	51.5	2.74	10.00	436
Millinocket	D	10.21	13.78	51.5	2.74	10.00	436
Millinocket	D	10.21	13.78	82.0	2.59	27.22	450
Woodland	D	15.55	11.15	25.9	1.68	16.76	339
Woodland	D	15.55	11.15	77.7	3.66	0.30	342
Woodland	D	15.55	11.15	71.3	2.44	0.27	444
Woodland	D	15.55	11.15	71.3	2.44	0.24	444
Woodland	D	15.55	11.15	79.6	1.22	0.30	344
Woodland	D	15.55	11.15	79.6	1.22	0.30	344
Old Town	D	10.49	9.73	43.6	2.41	8.14	439
Old Town	D	10.49	9.73	41.5	2.13	15.51	450
Old Town	D	10.49	9.73	41.5	2.13	8.29	450
Old Town	D	10.49	9.73	76.2	2.9	14.81	494
Old Town	D	10.49	9.73	76.8	1.52	5.33	348
Old Town	D	10.49	9.73	21.6	1.52	6.25	336
Old Town	D	10.49	9.73	12.2	1.16	18.29	328
Old Town	D	10.49	9.73	12.2	1.16	13.11	344
Lincoln	D	10.97	12.24	33.2	1.71	11.34	417
Lincoln	D	10.97	12.24	53.3	1.34	23.23	472
Lincoln	D	10.97	12.24	55.5	1.74	4.94	514
Lincoln	D	10.97	12.24	55.5	1.74	10.36	561
Lincoln	D	10.97	12.24	20.4	1.22	6.64	339
Lincoln	D	10.97	12.24	31.4	0.61	13.26	347
Lincoln	D	10.97	12.24	39.6	1.83	0.30	439
Lincoln	D	10.97	12.24	11.0	0.43	0.15	1228
Limestone	D	13.26	20.95	36.3	1.52	9.63	452
Limestone	D	13.26	20.95	36.3	1.52	9.63	428
Limestone	D	13.26	20.95	36.3	1.52	9.63	447

APPENDIX 3A (Cont'd)

Individual Stack Parameter Data for MESOPUFF II Runs

Source description	SOURCE GROUP	X-grid	Y-grid	HTSTAK (m) stack ht	D (m) stack dia	W (m/s) exit vel	TSTAK (°K) temp
Limestone	D	13.26	20.95	60.4	1.52	10.18	469
Limestone	D	13.26	20.95	60.4	1.52	10.18	475
Fort Fairfield	D	13.26	20.95	65.8	2.62	0.15	419
Fort Fairfield	D	13.26	20.95	44.8	0.91	17.25	561
Fort Fairfield	D	13.26	20.95	44.8	0.91	17.25	561
Brewer	D	9.90	8.95	45.7	3.05	11.28	450
Brewer	D	9.90	8.95	45.7	3.05	11.28	450
Bathurst (Area source)	C	21.50	24.50				
Edmundston (Area source)	C	12.00	24.00				
Fredericton (Area source)	B	18.20	15.60				
Moncton (Area source)	B	26.00	17.00				
St. John (Area source)	B	20.50	12.00				
Campbellton (Area source)	C	18.50	27.00				

A Coleson Cove TGS alone (CC)
B New Brunswick South (NBS)
C New Brunswick North (NBN)
D Major out of province sources in Maine, Nova Scotia and Quebec that are located in the model domain

APPENDIX 3B

Seasonal SO_2 Emission Rate (g/s) for Individual Stacks Used on MESOPUFF II Model

Source description	SOURCE GROUP	season 1	season 2	season 3	season 4	season 5	season 6	season 7	season 8
St. Anne-Nackawic Pulp Co. Ltd.	C	104.0	104.0	104.0	104.0	104.0	104.0	104.0	104.0
Fraser Inc., Edmundston	C	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Fraser Inc., Edmundston	C	80.3	80.3	80.3	80.3	80.3	80.3	80.3	80.3
Fraser Inc., Edmundston	C	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Fraser Inc., Edmundston	C	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Atholville Pulp	C	52.4	52.4	52.4	52.4	52.4	52.4	52.4	52.4
Atholville Pulp	C	106.7	106.7	106.7	106.7	106.7	106.7	106.7	106.7
Atholville Pulp	C	165.2	165.2	165.2	165.2	165.2	165.2	165.2	165.2
Atholville Pulp	C	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1
NB Power - Dalhousie	C	70.9	251.5	288.2	250.8	226.1	238.4	338.9	184.7
NB Power - Dalhousie	C	1165.7	1720.3	2398.3	1100.3	1310.0	1856.7	2186.6	1139.5
NBIP	C	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0
BMS Smelter	C	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BMS Smelter	C	102.3	102.3	150.2	175.3	175.3	175.3	175.3	175.3
BMS Smelter	C	186.3	186.3	144.2	122.1	122.1	122.1	122.1	122.1
NB Power - Chatham	B	20.5	12.9	39.9	13.8	0.2	12.2	16.3	4.6
Miramichi Pulp & Paper Ind.	B	0.8	0.8	1.1	1.3	1.3	1.3	1.9	2.3
Miramichi Pulp & Paper Ind.	B	22.7	22.7	30.8	35.1	35.1	35 1	54.0	64.0
Miramichi Pulp & Paper Ind.	B	2.7	2.7	3.3	3.6	3.6	3.6	3.5	3.5
Miramichi Pulp & Paper Ind.	B	12.9	12.9	17.5	19.9	19.9	19.9	30.7	36.3
NB Power - Coleson Cove	A	1314.6	1944.5	3048.5	2074.9	1953.6	2354.1	3181.3	2295.0
NB Power - Courtenay Bay	B	177.6	269.4	649.4	405.1	144.0	504.9	781.1	582.9
NB Power - Grand Lake	B	946.6	386.8	1070.4	508.7	889.8	1046.5	1131.5	565.2
Consolidated Bathurst (Pulp mill)	C	16.8	16.8	16.8	16.8	16.8	16.8	16.8	16.8
Utopia - pulp mill	B	44.6	44.6	44.6	44.6	44.6	44.6	44.6	44.6
Rothesay Paper	B	14.3	14.3	14.3	14.3	14.3	14.3	14.3	14.3
Lantic Sugar	B	28.5	28.5	28.5	28.5	28.5	28.5	28.5	28.5
Saint John Regional Hospital	B	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Irving Pulp and Paper (Fuel)	B	81.2	81.2	81.2	81.2	81.2	81.2	81.2	81.2
Irving Refinery	B	48.6	54.8	50.9	23.5	36.3	49.8	45.8	50.6
Irving Refinery	B	48.6	54.8	50.9	23.5	36.3	49.8	45.8	50.6
Irving Refinery	B	6.3	6.2	5.0	4.4	5.1	4.6	7.9	4.4
Irving Refinery	B	6.3	6.2	5.0	4.4	5.1	4.6	7.9	4.4
Irving Refinery	B	2.9	12.3	18.7	4.1	7.1	17.1	24.4	21.9
Irving Refinery	B	2.9	12.3	18.7	4.1	7.1	17.1	24.4	21.9
Irving Refinery	B	2.9	12.3	18.7	4.1	7.1	17.1	24.4	21.9
Irving Refinery	B	2.9	12.3	18.7	4.1	7.1	17.1	24.4	21.9
Irving Refinery	B	2.9	12.3	18.7	4.1	7.1	17.1	24.4	21.9
FlakeBoard	B	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
FlakeBoard	B	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
NS Power - Maccan GS	D	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8
NS Power - Trenton GS	D	431.3	431.3	431.3	431.3	431.3	431.3	431.3	431.3
Texaco Canada Inc	D	29.7	29.7	29.7	29.7	29.7	29.7	29.7	29.7
Texaco Canada Inc	D	29.7	29.7	29.7	29.7	29.7	29.7	29.7	29.7
Texaco Canada Inc	D	29.7	29.7	29.7	29.7	29.7	29.7	29.7	29.7
Texaco Canada Inc	D	29.7	29.7	29.7	29.7	29.7	29.7	29.7	29.7
Texaco Canada Inc	D	29.7	29.7	29.7	29.7	29.7	29.7	29.7	29.7
Texaco Canada Inc	D	29.7	29.7	29.7	29.7	29.7	29.7	29.7	29.7
NS Power - Tufts Cove GS	D	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9
NS Power - Tufts Cove GS	D	179.8	179.8	179.8	179.8	179.8	179.8	179.8	179.8

APPENDIX 3B (Cont'd)

Seasonal SO_2 Emission Rate (g/s) for Individual Stacks Used on MESOPUFF II Model

Source description	SOURCE GROUP	season 1	season 2	season 3	season 4	season 5	season 6	season 7	season 8
NS Power - Tufts Cove GS	D	379.6	379.6	379.6	379.6	379.6	379.6	379.6	379.6
NS Power - Point Tupper GS	D	672.3	672.3	672.3	672.3	672.3	672.3	672.3	672.3
Consol-Barthust, Dev Chaleurs	D	22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.9
Consol-Barthust, Dev Chaleurs	D	22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.9
Consol-Barthust, Dev Chaleurs	D	22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.9
Consol-Barthust, Dev Chaleurs	D	22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.9
La Compagnie Gaspesia Ltee	D	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
La Compagnie Gaspesia Ltee	D	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
La Compagnie Gaspesia Ltee	D	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
La Compagnie Gaspesia Ltee	D	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
F.F. Soucy Inc	D	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
F.F. Soucy Inc	D	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Soc Canadienne De Metaux Reynolds Lt	D	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5
Soc Canadienne De Metaux Reynolds Lt	D	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5
Soc Canadienne De Metaux Reynolds Lt	D	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5
Soc Canadienne De Metaux Reynolds Lt	D	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5
Soc Canadienne De Metaux Reynolds Lt	D	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5
Millinocket	D	60.1	60.1	60.1	60.1	60.1	60.1	60.1	60.1
Millinocket	D	62.8	62.8	62.8	62.8	62.8	62.8	62.8	62.8
Millinocket	D	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0
Millinocket	D	96.3	96.3	96.3	96.3	96.3	96.3	96.3	96.3
Millinocket	D	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Millinocket	D	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
Millinocket	D	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8
Millinocket	D	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Woodland	D	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Woodland	D	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Woodland	D	23.9	23.9	23.9	23.9	23.9	23.9	23.9	23.9
Woodland	D	23.9	23.9	23.9	23.9	23.9	23.9	23.9	23.9
Woodland	D	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Woodland	D	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Old Town	D	42.6	42.6	42.6	42.6	42.6	42.6	42.6	42.6
Old Town	D	20.4	20.4	20.4	20.4	20.4	20.4	20.4	20.4
Old Town	D	20.4	20.4	20.4	20.4	20.4	20.4	20.4	20.4
Old Town	D	29.7	29.7	29.7	29.7	29.7	29.7	29.7	29.7
Old Town	D	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Old Town	D	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Old Town	D	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Old Town	D	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Lincoln	D	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Lincoln	D	28.3	28.3	28.3	28.3	28.3	28.3	28.3	28.3
Lincoln	D	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
Lincoln	D	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5
Lincoln	D	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Lincoln	D	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Lincoln	D	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Lincoln	D	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Limestone	D	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Limestone	D	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
Limestone	D	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0

APPENDIX 3B (Cont'd)

Seasonal SO_2 Emission Rate (g/s) for Individual Stacks Used on MESOPUFF II Model

Source description	SOURCE GROUP	season 1	season 2	season 3	season 4	season 5	season 6	season 7	season 8
Limestone	D	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Limestone	D	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
Fort Fairfield	D	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Fort Fairfield	D	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Fort Fairfield	D	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Brewer	D	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2
Brewer	D	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2
Bathurst (Area source)	C	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
Edmundston (Area source)	C	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9
Fredericton (Area source)	B	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3
Moncton (Area source)	B	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2
St. John (Area source)	B	16.1	16.1	16.1	16.1	16.1	16.1	16.1	16.1
Campbellton (Area source)	C	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
Total in NB		5093	6042	8992	5732	5944	7509	9198	6340
Annual Total in NB (ktonne)					203.9				228.6
Total for NB Power		3696	4585	7495	4354	4524	6013	7636	4772
Annual Total For NB Power (ktonne)					158.7				180.9
Annual Total NB sources other than NB Power (ktonne)					45.2				47.7

A Coleson Cove TGS alone (CC)
B New Brunswick South (NBS)
C New Brunswick North (NBN)
D Major out of province sources in Maine, Nova Scotia and Quebec that are located in the model domain

APPENDIX 4

APPENDIX 4

Sample Output Listing for the Input Parameters Used for MESOPUFF II Runs

```
                    MESOPUFF II   VERSION  4.02   LEVEL 880408
**********************************************************************************
MESOPUFF II VERSION 4.02 - Season 1 Coleson Cove Sensitivity 5 (fall canopy)

GENERAL RUN INFORMATION:

      YEAR OF RUN (NSYR) = 88
      JULIAN DAY OF START OF RUN (NSDAY) = 145
      HOUR OF START OF RUN (NSHR) =  0
      LENGTH OF RUN (NADVTS) = 2376 (HOURS)
      NUMBER OF POINT SOURCES (NPTS) =  1
      NUMBER OF AREA (URBAN) SOURCES (NAREAS) =  0
      NUMBER OF NONGRIDDED RECEPTORS (NREC) =  26
      NUMBER OF POLLUTANT SPECIES (NSPEC) =  5

COMPUTATIONAL VARIABLES:

      CONCENTRATION AVERAGING TIME (IAVG) =    1 (HOUR(S))
      PUFF RELEASE RATE (NPUF) =   1 (PUFFS/HOUR)
      MINIMUM SAMPLING RATE (NSAMAD) =  2 (SAMPLES/HOUR)
      SAMPLING RATE VARIED WITH WIND SPEED ? (LVSAMP) = T
      SAMPLING RATE WIND SPEED INTERVAL (WSAMP) =  2.00 (M/S)
      CONCENTRATIONS CALCULATED AT SAMPLING GRID POINTS ? (LSGRID) = F
      PUFFS YOUNGER THAN "AGEMIN" SECONDS ARE NOT SAMPLED (AGEMIN) = 900. (SECONDS)

GRID INFORMATION:

      BEGINNING OF COMPUTATIONAL GRID IN X-DIRECTION (IASTAR) =  1
      END OF COMPUTATIONAL GRID IN X-DIRECTION (IASTOP) = 40
      BEGINNING OF COMPUTATIONAL GRID IN Y-DIRECTION (JASTAR) =  1
      END OF COMPUTATIONAL GRID IN Y-DIRECTION (JASTOP) = 40
      BEGINNING OF SAMPLING GRID IN X-DIRECTION (ISASTR) =  5
      END OF SAMPLING GRID IN X-DIRECTION (ISASTP) = 35
      BEGINNING OF SAMPLING GRID IN Y-DIRECTION (JSASTR) =  5
      END OF SAMPLING GRID IN Y-DIRECTION (JSASTP) = 35
      SAMPLING GRID SPACING FACTOR (MESHDN) =  1

TECHNICAL OPTIONS:

      GAUSSIAN VERTICAL CONCENTRATION DISTRIBUTION ? (LGAUSS) = T
      CHEMICAL PROCESSES MODELED ? (LCHEM) = T
      DRY DEPOSITION MODELED ? (LDRY) = T
      WET REMOVAL MODELED ? (LWET) = T
      3 VERTICAL LAYERS ? (L3VL) = T

OUTPUT OPTIONS:

      CONCENTRATIONS STORED ON TAPE ? (LTAPE) = T
      CONCENTRATIONS PRINTED ? (LPRINT) = T
      PRINT INTERVAL (IPRINF) = 2376
      PUFF PARAMETERS PRINTED EACH SAMPLING STEP ? (LDB) = F
      TIME STEPS FOR WHICH PUFF PARAMETERS PRINTED (NN1,NN2) =    0,    0
      WET FLUXES AT GRIDDED RECEPTORS COMPUTED ? (LWETG) = F
      WET FLUXES AT NONGRIDDED RECEPTORS COMPUTED ? (LWETNG) = T
      DRY FLUXES AT GRIDDED RECEPTORS COMPUTED ? (LDRYG) = F
      DRY FLUXES AT NONGRIDDED RECEPTORS COMPUTED ? (LDRYNG) = T
      WET AND DRY FLUXES STORED ON TAPE ? (LSAVEF) = T
      WET AND DRY FLUXES PRINTED ? (LPRFLX) = T
```

APPENDIX 4 (Cont'd)

Sample Output Listing for the Input Parameters Used for MESOPUFF II Runs

```
                    MESOPUFF II   VERSION  4.02   LEVEL 880408
**********************************************************************************************

DEFAULT OVERRIDE OPTIONS (0=NO,1=YES)
USER INPUT SIGY, SIGZ VARIABLES (IOPTS(1)) =                1
USER INPUT VERTICAL DIFFUSIVITY CONSTANTS (IOPTS(2)) =      0
USER INPUT DRY DEP. SO2 CANOPY RESISTANCES (IOPTS(3)) =     1
USER INPUT OTHER DRY DEP. CONSTANTS (IOPTS(4)) =            0
USER INPUT WET REMOVAL CONSTANTS (IOPTS(5)) =               0
USER INPUT CHEMICAL TRANSFORMATION VARIABLES (IOPTS(6)) =   0

SIGY, SIGZ VARIABLES:
AY =            0.36000   0.25000   0.19000   0.13000   0.09600   0.06300
BY =            0.90000   0.90000   0.90000   0.90000   0.90000   0.90000
AZ =            0.00023   0.05800   0.11000   0.57000   0.85000   0.77000
BZ =            2.10000   1.09000   0.91000   0.58000   0.47000   0.42000
AZT (IN M) =    5.00000   3.87300   2.73900   1.87100   1.22500   0.70700
TMDEP =     10000. (M)
STABILITY CLASS USED IN SIGY, SIGZ CALCULATIONS FOR PUFFS ABOVE BOUNDARY LAYER (JSUP) =
5
    (0 = BOUNDARY LAYER STABILITY CLASS, 5 = E STABILITY, 6 = F STABILITY)

VERTICAL DIFFUSIVITY CONSTANTS:
CON1K =      0.010 (M**2/S)
CON2K =      0.100 (M**2/S)

LAND USE CATEGORY   SO2 CANOPY RESISTANCE (S/M)
                     A,B,C       D         E         F
   1                200.00    300.00    500.00    100.00
   2                300.00    400.00    500.00    100.00
   3                200.00    300.00    400.00    100.00
   4                500.00    500.00   1200.00    100.00
   5                200.00    400.00   1000.00    100.00
   6                400.00    500.00   1000.00    300.00
   7                300.00    400.00    500.00    200.00
   8                700.00    800.00   2000.00   1500.00
   9                200.00    100.00    300.00    100.00
  10                200.00    300.00    600.00    200.00
  11                500.00    500.00   1000.00    700.00
  12                  5.00      5.00      5.00      2.00

DRY DEPOSITION CONSTANTS:
CANOPY RESISTANCE FOR NOX IN S/M (RCNOX) =  130.00 (A,B,C)    500.00 (D)   1500.00 (E)
1500.00 (F)
SURFACE RESISTANCE CONSTANT FOR GASES (RSGCON) =    2.60
SURFACE RESISTANCE FOR PARTICLES (RSPART) = 1000.00 (S/M)

WET REMOVAL CONSTANTS:
                          SO2        SO4        NOX       HNO3       NO3
WA(LIQUID PRECIP.)    3.00E-05   1.00E-04   0.00E+00   6.00E-05   1.00E-04
WA (FROZEN PRECIP.)    0.00E+00   3.00E-05   0.00E+00   0.00E+00   3.00E-05

WHERE Q/Q0 = EXP(-WA * (P/P0) * DT)
     Q0 IS POLLUTANT MASS IN PUFF AT TIME T
     Q IS POLLUTANT MASS IN PUFF AT TIME T + DT
     WA IS THE WET REMOVAL CONSTANT (1/S)
     P IS THE PRECIPITATION RATE (MM/HR)
     P0 IS A REFERENCE PRECIPITATION RATE OF 1 MM/HR
     DT IS THE SAMPLING INTERVAL
```

APPENDIX 4 (Cont'd)

Sample Output Listing for the Input Parameters Used for MESOPUFF II Runs

```
                    MESOPUFF II   VERSION  4.02   LEVEL 880408
*******************************************************************************

CHEMICAL TRANSFORMATION VARIABLES:
      SOX TRANSFORMATION METHOD FLAG (MSOX) =  2
         0 - NO TRANSFORMATION
         1 - USER SPECIFIED
         2 - ERT THEORETICAL EQUATION
         3 - GILLANI EQUATION
         4 - HENRY EQUATION FOR ST. LOUIS
         5 - HENRY EQUATION FOR LOS ANGELES
      NOX TRANSFORMATION METHOD FLAG (MNOX) =  2
         0 - NO TRANSFORMATION
         1 - USER SPECIFIED
         2 - ERT THEORETICAL EQUATION
      OZONE INPUT METHOD FLAG (MO3) =  0
         0 - DEFAULT OZONE VALUE USED
         1 - HOURLY OZONE VALUES READ
      DEFAULT BACKGROUND OZONE (CO3B) =   80.0 (PPB)
      TOTAL AMMONIA CONCENTRATION (CTNH3) =   10.0 (PPB)
      NIGHTTIME TRANSFORMATION RATES:
         SO2 LOSS RATE (RNITE(1)) =   0.2 (%/HOUR)
         NOX LOSS RATE (RNITE(2)) =   2.0 (%/HOUR)
         TOTAL NO3 FORMATION RATE (RNITE(3)) =   2.0 (%/HOUR)
```

APPENDIX 5

APPENDIX 5-1

SEASONAL AND ANNUAL WET SULPHUR DEPOSITION (kg/ha) AT SELECTED RECEPTORS PREDICTED BY THE MESOPUFF II MODEL

	SEASON 1 - SUMMER 88									SEASON 2 - FALL 88								
	RAINFALL		ADJUSTED							RAINFALL		ADJUSTED						
RECEPTOR	OBSERVED	MODEL INPUT	DEP	CC	NBS	NBN	OOP	BKGRD	TOTAL	OBSERVED	MODEL INPUT	DEP	CC	NBS	NBN	OOP	BKGRD	TOTAL
	(mm)	(mm)	kg S/ha							(mm)	(mm)	kg S/ha						
3	280.3	315.5	1.76	0.017	0.036	0.028	0.015	1.743	1.839	233.9	235.7	0.89	0.016	0.015	0.008	0.011	0.531	0.581
4	316.6	328.2	2.47	0.024	0.059	0.022	0.024	1.968	2.097	338.6	293.0	0.80	0.110	0.102	0.005	0.024	0.769	1.010
6	305.7	233.2	2.56	0.054	0.046	0.005	0.042	1.901	2.048	289.5	338.8	0.77	0.100	0.096	0.002	0.012	0.658	0.868
7	310.9	233.2	2.27	0.036	0.173	0.015	0.025	1.933	2.182	307.8	338.8	0.95	0.022	0.021	0.018	0.010	0.699	0.770
8	291.5	252.3	2.70	0.023	0.057	0.102	0.015	1.812	2.009	295.8	205.0	1.24	0.014	0.013	0.054	0.016	0.672	0.770
9	318.4	328.2	1.99	0.023	0.042	0.026	0.016	1.980	2.087	306.0	293.0	0.98	0.032	0.029	0.013	0.015	0.695	0.784
12	323.3	330.1	2.64	0.429	0.168	0.002	0.034	2.010	2.644	387.5	405.6	1.24	0.303	0.299	0.002	0.007	0.880	1.492
13	316.2	330.1	2.39	0.171	0.040	0.002	0.029	1.966	2.207	424.4	405.6	1.41	0.400	0.388	0.002	0.008	0.964	1.762
14	279.9	330.1	1.64	0.134	0.082	0.003	0.033	1.740	1.992	233.8	405.6	0.82	0.139	0.133	0.002	0.004	0.531	0.808
15	335.8	233.2	2.59	0.136	0.115	0.003	0.042	2.088	2.384	307.5	338.8	0.84	0.122	0.118	0.002	0.009	0.698	0.949
16	345.2	330.1	2.35	0.133	0.047	0.002	0.033	2.146	2.361	419.0	405.6	1.44	0.052	0.052	0.001	0.009	0.952	1.066
17	318.0	233.2	1.92	0.181	0.084	0.003	0.041	1.977	2.285	355.6	338.8	0.97	0.268	0.258	0.002	0.011	0.808	1.348
18	265.8	330.1	2.36	0.103	0.074	0.004	0.026	1.653	1.859	243.6	405.6	0.85	0.067	0.065	0.002	0.004	0.553	0.691
19	316.9	233.2	2.18	0.229	0.134	0.003	0.044	1.970	2.380	306.4	338.8	0.86	0.149	0.148	0.002	0.007	0.696	1.001
20	292.4	233.2	2.27	0.121	0.101	0.003	0.039	1.818	2.082	315.8	338.8	0.78	0.172	0.165	0.002	0.010	0.717	1.066
21	381.4	233.2	2.80	0.305	0.109	0.003	0.062	2.371	2.849	387.4	338.8	1.25	0.019	0.020	0.001	0.013	0.880	0.933
23	386.2	330.1	2.34	0.242	0.176	0.003	0.040	2.401	2.862	419.1	405.6	1.36	0.303	0.290	0.003	0.007	0.952	1.555
27	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
24	318.1	245.7	1.10	0.028	0.024	0.019	0.039	1.978	2.088	337.2	300.4	0.65	0.080	0.055	0.008	0.018	0.766	0.907
26	230.0	252.3	1.82	0.014	0.022	0.031	0.009	1.430	1.507	215.3	205.0	1.17	0.011	0.010	0.023	0.012	0.489	0.545
30	343.2	286.5	1.80	0.017	0.011	0.001	0.012	2.134	2.175	470.8	376.3	0.92	0.007	0.007	0.002	0.013	1.069	1.099
AVE ALL	313.8	281.1	2.20	0.12	0.08	0.01	0.03	1.95	2.20	329.8	335.7	1.00	0.12	0.11	0.01	0.01	0.75	1.00
AVE CC/SJ	323.7	286.1	2.32	0.20	0.10	0.00	0.04	2.01	2.35	345.5	375.2	1.07	0.18	0.18	0.00	0.01	0.78	1.15

(1) RECEPTOR 13 IS NOT INCLUDED IN THE ANALYSIS

(2) * NOT AVAILABLE

(3) SOURCES ARE GROUPED TOGETHER AS FOLLOWS:

CC = COLESON COVE TGS ALONE

NBS = SOURCES IN NEW BRUNSWICK SOUTH

NBN = SOURCES IN NEW BRUNSWICK NORTH

OOP = SOURCES OUTSIDE NEW BRUNSWICK

CONCORD ENVIRONMENTAL

APPENDIX 5-1 (Cont'd)

SEASONAL AND ANNUAL WET SULPHUR DEPOSITION (kg/ha) AT SELECTED RECEPTORS PREDICTED BY THE MESOPUFF II MODEL

	SEASON 3 - WINTER 88/89									SEASON 4 - SPRING 89								
	RAINFALL		ADJUSTED							RAINFALL		ADJUSTED						
RECEPTOR	OBSERVED (mm)	MODEL INPUT (mm)	DEP kg S/ha	CC	NBS	NBN	OOP	BKGRD	TOTAL	OBSERVED (mm)	MODEL INPUT (mm)	DEP kg S/ha	CC	NBS	NBN	OOP	BKGRD	TOTAL
3	162.5	226.1	0.52	0.003	0.004	0.002	0.002	0.611	0.623	275.8	145.5	1.65	0.040	0.023	0.024	0.020	1.328	1.435
4	193.8	195.9	0.52	0.007	0.022	0.005	0.003	0.729	0.766	235.4	116.6	1.45	0.150	0.079	0.005	0.040	1.133	1.407
6	144.0	200.8	0.56	0.007	0.003	0.000	0.006	0.542	0.558	239.0	188.8	1.36	0.119	0.036	0.006	0.015	1.151	1.327
7	203.0	200.8	0.54	0.013	0.011	0.004	0.004	0.763	0.796	243.7	188.8	1.22	0.068	0.063	0.007	0.029	1.173	1.361
8	170.4	226.7	0.49	0.002	0.003	0.004	0.003	0.641	0.654	269.4	160.5	1.61	0.067	0.021	0.060	0.017	1.297	1.463
9	175.4	195.9	0.44	0.005	0.010	0.003	0.003	0.660	0.681	258.5	116.6	1.43	0.053	0.054	0.017	0.051	1.245	1.420
12	248.1	260.1	1.34	0.039	0.004	0.001	0.006	0.933	0.982	363.3	205.3	2.20	0.572	0.239	0.001	0.030	1.749	2.591
13	348.1	260.1	1.73	0.008	0.005	0.001	0.005	1.309	1.328	441.8	205.3	3.30	0.706	0.121	0.001	0.031	2.127	2.986
14	260.7	260.1	1.24	0.171	0.051	0.002	0.004	0.980	1.209	335.5	205.3	2.14	0.329	0.085	0.001	0.027	1.615	2.059
15	201.4	200.8	0.81	0.040	0.007	0.001	0.005	0.757	0.810	348.4	188.8	1.98	0.493	0.088	0.004	0.020	1.677	2.281
16	241.9	260.1	1.20	0.005	0.014	0.000	0.003	0.910	0.932	383.9	205.3	2.54	0.281	0.076	0.004	0.023	1.848	2.233
17	271.5	200.8	0.96	0.052	0.008	0.001	0.008	1.021	1.090	301.5	188.8	2.06	0.271	0.090	0.003	0.018	1.452	1.834
18	214.4	260.1	1.01	0.137	0.037	0.002	0.003	0.806	0.985	337.8	205.3	1.76	0.239	0.082	0.002	0.021	1.626	1.971
19	215.3	200.8	0.97	0.034	0.008	0.001	0.005	0.810	0.858	301.6	188.8	1.76	0.474	0.089	0.002	0.019	1.452	2.036
20	203.0	200.8	0.73	0.023	0.005	0.001	0.005	0.763	0.798	309.2	188.8	1.66	0.287	0.065	0.005	0.022	1.489	1.868
21	230.3	200.8	1.08	0.013	0.003	0.000	0.006	0.866	0.888	338.0	188.8	2.56	0.190	0.147	0.002	0.024	1.627	1.991
23	280.3	260.1	1.43	0.135	0.[illegible]	0.002	0.007	1.054	1.242	329.0	205.3	2.26	0.272	0.225	0.002	0.033	1.584	2.116
27	201.0	260.1	1.11	0.190	0.013	0.001	0.003	0.756	0.963	316.9	205.3	2.26	0.124	0.280	0.002	0.032	1.535	1.974
24	220.8	264.0	0.59	0.009	0.003	0.001	0.006	0.830	0.849	340.8	93.4	1.21	0.217	0.071	0.116	0.045	1.641	2.090
26	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
30	348.2	323.3	1.04	0.009	0.005	0.001	0.004	1.309	1.329	320.2	82.6	1.58	0.008	0.003	0.000	0.016	1.542	1.569
AVE ALL	226.7	232.9	0.92	0.05	0.01	0.00	0.00	0.85	0.92	314.6	173.7	1.90	0.25	0.10	0.01	0.03	1.51	1.90
AVE CC/SJ	243.0	235.4	1.13	0.07	0.02	0.00	0.00	0.91	1.01	342.4	198.4	2.21	0.35	0.13	0.00	0.02	1.65	2.16

(1) RECEPTOR 13 IS NOT INCLUDED IN THE ANALYSIS

(2) * NOT AVAILABLE

(3) SOURCES ARE GROUPED TOGETHER AS FOLLOWS:

CC = COLESON COVE TGS ALONE

NBS = SOURCES IN NEW BRUNSWICK SOUTH

NBN = SOURCES IN NEW BRUNSWICK NORTH

OOP = SOURCES OUTSIDE NEW BRUNSWICK

OOP = SOURCES OUTSIDE NEW BRUNSWICK

CONCORD ENVIRONMENTAL

APPENDIX 5-1 (Cont'd)

SEASONAL AND ANNUAL WET SULPHUR DEPOSITION (kg/ha) AT SELECTED RECEPTORS PREDICTED BY THE MESOPUFF II MODEL

	SEASON 5 - SUMMER 89									SEASON 6 - FALL 89								
	RAINFALL		ADJUSTED							RAINFALL		ADJUSTED						
RECEPTOR	OBSERVED (mm)	MODEL INPUT (mm)	DEP kg S/ha	CC	NBS	NBN	OOP	BKGRD	TOTAL	OBSERVED (mm)	MODEL INPUT (mm)	DEP kg S/ha	CC	NBS	NBN	OOP	BKGRD	TOTAL
3	406.6	206.0	1.70	0.020	0.025	0.120	0.028	2.725	2.917	227.1	189.6	1.06	0.021	0.019	0.008	0.024	0.708	0.781
4	360.6	314.6	1.99	0.080	0.123	0.021	0.014	2.416	2.654	279.7	162.8	0.66	0.098	0.134	0.030	0.024	0.872	1.158
6	185.2	373.5	0.97	0.014	0.010	0.002	0.014	1.241	1.280	258.1	229.8	1.22	0.044	0.009	0.005	0.022	0.805	0.884
7	342.1	373.5	1.75	0.034	0.033	0.018	0.017	2.292	2.394	323.8	229.8	1.01	0.033	0.043	0.012	0.030	1.010	1.128
8	285.6	173.0	1.06	0.006	0.013	0.168	0.020	1.914	2.120	283.3	189.0	1.12	0.015	0.012	0.063	0.010	0.821	0.921
9	339.9	314.6	1.11	0.027	0.043	0.053	0.013	2.278	2.414	189.2	162.8	0.66	0.025	0.037	0.042	0.016	0.590	0.709
12	216.2	243.8	1.88	0.442	0.048	0.002	0.008	1.449	1.950	323.9	355.6	1.35	0.207	0.100	0.007	0.012	1.010	1.336
13	294.8	243.8	2.63	0.241	0.065	0.002	0.008	1.976	2.292	384.0	355.6	1.87	0.051	0.037	0.006	0.013	1.197	1.305
14	193.4	243.8	2.48	0.353	0.121	0.003	0.006	1.296	1.780	312.4	355.6	1.35	0.226	0.173	0.007	0.012	0.974	1.392
15	277.2	373.5	2.13	0.013	0.029	0.002	0.011	1.858	1.913	316.6	229.8	1.21	0.181	0.029	0.010	0.023	0.987	1.230
16	277.6	243.8	2.93	0.105	0.026	0.002	0.011	1.860	2.004	426.5	355.6	1.80	0.210	0.061	0.007	0.015	1.330	1.623
17	327.9	373.5	2.93	0.067	0.031	0.002	0.012	2.197	2.309	371.9	229.8	1.12	0.205	0.046	0.010	0.027	1.159	1.447
18	270.1	243.8	2.64	0.393	0.123	0.005	0.013	1.810	2.344	306.9	355.6	1.25	0.212	0.093	0.009	0.016	0.957	1.286
19	246.0	373.5	1.92	0.104	0.036	0.002	0.008	1.648	1.799	302.4	229.8	0.94	0.440	0.050	0.010	0.024	0.943	1.466
20	283.6	373.5	2.45	0.018	0.030	0.003	0.019	1.900	1.970	286.2	229.8	1.01	0.092	0.033	0.008	0.020	0.899	1.052
21	282.6	373.5	3.07	0.071	0.017	0.001	0.011	1.894	1.994	375.5	229.8	1.45	0.023	0.066	0.007	0.027	1.171	1.293
23	250.6	243.8	2.82	0.524	0.219	0.003	0.006	1.679	2.431	192.3	355.6	1.05	0.175	0.101	0.005	0.007	0.600	0.887
27	262.1	243.8	2.99	0.583	0.338	0.003	0.006	1.756	2.686	415.5	355.6	1.73	0.341	0.100	0.010	0.013	1.295	1.759
24	281.9	237.3	1.33	0.004	0.005	0.008	0.015	1.889	1.921	441.4	191.9	1.38	0.028	0.027	0.012	0.056	1.376	1.499
26	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
30	210.2	230.4	1.83	0.018	0.005	0.001	0.008	1.409	1.440	420.0	299.1	1.26	0.021	0.017	0.004	0.013	1.309	1.365
AVE ALL	279.7	289.9	2.13	0.16	0.07	0.02	0.01	1.87	2.13	320.9	264.7	1.23	0.13	0.06	0.01	0.02	1.00	1.23
AVE CC/SJ	265.2	297.8	2.57	0.24	0.09	0.00	0.01	1.78	2.12	334.7	303.2	1.34	0.20	0.07	0.01	0.02	1.04	1.34

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CONCORD ENVIRONMENTAL

SEASONAL AND ANNUAL WET SULPHUR DEPOSITION (kg/ha) AT SELECTED RECEPTORS PREDICTED BY THE MESOPUFF II MODEL

	SEASON 7 - WINTER 89/90									SEASON 8 - SPRING 90 (1)								
	RAINFALL		ADJUSTED							RAINFALL		ADJUSTED						
RECEPTOR	OBSERVED (mm)	MODEL INPUT (mm)	DEP kg S/ha	CC	NBS	NBN	OOP	BKGRD	TOTAL	OBSERVED (mm)	MODEL INPUT (mm)	DEP kg S/ha	CC	NBS	NBN	OOP	BKGRD	TOTAL
3	186.8	326.7	0.749	0.006	0.011	0.005	0.005	0.822	0.850	175.0	140.9	0.979	0.011	0.010	0.009	0.022	0.649	0.701
4	292.6	311.6	0.999	0.038	0.044	0.008	0.007	1.289	1.386	329.6	160.4	1.256	0.084	0.126	0.015	0.051	1.222	1.499
6	197.1	332.9	1.495	0.042	0.024	0.002	0.010	0.868	0.945	250.8	249.8	1.007	0.062	0.052	0.002	0.018	0.930	1.063
7	210.7	332.9	1.003	0.027	0.033	0.006	0.007	0.927	1.000	302.5	249.8	1.599	0.003	0.022	0.012	0.026	1.121	1.184
8	180.7	263.2	0.743	0.002	0.006	0.008	0.003	0.795	0.815	199.8	137.8	1.746	0.007	0.010	0.124	0.020	0.741	0.902
9	230.0	311.6	0.933	0.030	0.039	0.008	0.005	1.012	1.095	240.5	160.4	0.899	0.019	0.028	0.020	0.024	0.892	0.982
12	236.2	381.4	1.116	0.030	0.087	0.002	0.006	1.040	1.166	164.9	318.5	0.998	0.108	0.141	0.001	0.009	0.611	0.870
13	459.4	381.4	2.555	0.171	0.012	0.004	0.009	2.022	2.219	426.3	318.5	2.837	5.547	0.106	0.002	0.024	1.306	6.984
14	270.8	381.4	1.449	0.194	0.030	0.003	0.008	1.192	1.427	314.0	318.5	1.517	0.174	0.144	0.002	0.013	1.164	1.499
15	246.0	332.9	1.286	0.026	0.048	0.003	0.010	1.083	1.170	312.1	249.8	1.579	0.162	0.068	0.003	0.020	1.157	1.410
16	261.8	381.4	1.881	0.009	0.007	0.002	0.004	1.152	1.176	412.4	318.5	2.407	0.194	0.060	0.001	0.020	1.529	1.805
17	291.8	332.9	1.328	0.070	0.034	0.003	0.011	1.284	1.403	439.4	249.8	2.064	0.163	0.236	0.003	0.027	1.629	2.058
18	290.7	381.4	1.296	0.087	0.079	0.005	0.009	1.280	1.458	390.0	318.5	1.590	0.093	0.085	0.004	0.012	1.446	1.640
19	273.7	332.9	1.382	0.014	0.035	0.003	0.011	1.205	1.268	327.7	249.8	1.422	0.157	0.094	0.003	0.017	1.215	1.487
20	244.6	332.9	1.143	0.045	0.039	0.003	0.011	1.077	1.175	365.6	249.8	1.448	0.190	0.081	0.004	0.020	1.355	1.651
21	292.9	332.9	1.462	0.027	0.024	0.003	0.010	1.289	1.354	406.6	249.8	2.180	0.493	0.109	0.002	0.030	1.507	2.141
23	336.5	381.4	1.831	0.355	0.135	0.004	0.009	1.481	1.984	434.7	318.5	2.206	0.437	0.306	0.003	0.022	1.611	2.379
27	270.9	381.4	1.877	0.184	0.043	0.003	0.006	1.192	1.429	412.3	318.5	2.241	0.614	0.503	0.002	0.022	1.528	2.669
24	295.8	367.6	0.705	0.009	0.018	0.006	0.008	1.302	1.343	502.6	246.5	1.314	0.029	0.027	0.013	0.049	1.863	1.981
26	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
30	344.2	447.8	0.963	0.006	0.006	0.002	0.004	1.515	1.532	461.8	282.4	1.201	0.001	0.000	0.001	0.017	1.712	1.731
AVE ALL	270.7	351.4	1.31	0.07	0.04	0.00	0.01	1.19	1.31	339.1	252.0	1.56	0.16	0.11	0.01	0.02	1.26	1.56
AVE CC/SJ	289.6	361.2	1.55	0.10	0.05	0.00	0.01	1.27	1.44	361.8	287.3	1.79	0.25	0.17	0.00	0.02	1.34	1.78

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APPENDIX 5-1 (Cont'd)

SEASONAL AND ANNUAL WET SULPHUR DEPOSITION (kg/ha) AT SELECTED RECEPTORS PREDICTED BY THE MESOPUFF II MODEL

	YEAR 1									YEAR 2(1)								
	RAINFALL		ADJUSTED							RAINFALL		ADJUSTED						
RECEPTOR	OBSERVED (mm)	MODEL INPU (mm)	DEP kg S/ha	CC	NBS	NBN	OOP	BKGRD	TOTAL	OBSERVE (mm)	MODEL INPU (mm)	DEP kg S/ha	CC	NBS	NBN	OOP	BKGRD	TOTAL
3	953	923	4.83	0.076	0.078	0.062	0.050	4.213	4.479	996	863	4.49	0.059	0.065	0.142	0.079	4.904	5.249
4	1084	934	5.04	0.290	0.262	0.036	0.091	4.600	5.280	1263	949	4.91	0.300	0.427	0.074	0.096	5.799	6.697
6	978	962	5.27	0.281	0.182	0.013	0.076	4.251	4.801	891	1186	4.68	0.161	0.095	0.012	0.063	3.843	4.173
7	1065	962	4.98	0.140	0.288	0.043	0.069	4.569	5.109	1179	1186	5.37	0.097	0.131	0.048	0.080	5.351	5.707
8	1027	845	6.04	0.107	0.095	0.221	0.051	4.422	4.896	929	763	4.66	0.030	0.041	0.363	0.053	4.271	4.758
9	1058	934	4.85	0.113	0.135	0.060	0.086	4.579	4.973	1000	949	3.60	0.101	0.147	0.123	0.057	4.772	5.199
12	1322	1201	7.42	1.344	0.709	0.006	0.077	5.572	7.709	941	1299	5.35	0.788	0.376	0.012	0.035	4.110	5.321
13	1531	1201	8.84	1.286	0.554	0.005	0.073	6.366	8.284	1365	1299	9.89	6.009	0.220	0.015	0.055	6.501	12.800
14	1110	1201	5.84	0.773	0.351	0.008	0.068	4.867	6.068	1091	1299	6.79	0.948	0.468	0.016	0.040	4.626	6.097
15	1193	962	6.23	0.791	0.327	0.009	0.076	5.221	6.424	1152	1186	6.21	0.383	0.174	0.017	0.064	5.084	5.723
16	1390	1201	7.52	0.471	0.188	0.008	0.069	5.856	6.592	1378	1299	9.02	0.519	0.155	0.012	0.050	5.871	6.608
17	1247	962	5.91	0.772	0.441	0.009	0.077	5.258	6.557	1431	1186	7.44	0.505	0.346	0.019	0.077	6.270	7.218
18	1062	1201	5.97	0.546	0.256	0.010	0.053	4.639	5.505	1258	1299	6.78	0.784	0.360	0.022	0.049	5.492	6.728
19	1140	962	5.77	0.885	0.379	0.007	0.075	4.928	6.275	1150	1186	5.66	0.715	0.215	0.018	0.061	5.011	6.020
20	1120	962	5.44	0.602	0.337	0.010	0.077	4.787	5.813	1182	1186	6.05	0.346	0.183	0.018	0.070	5.231	5.847
21	1337	962	7.69	0.527	0.279	0.007	0.104	5.745	6.660	1358	1186	8.17	0.614	0.216	0.013	0.078	5.861	6.783
23	1415	1201	7.39	0.952	0.736	0.010	0.086	5.991	7.775	1214	1299	7.90	1.492	0.762	0.014	0.043	5.372	7.682
27	*	*	*	*	*	*	*	*	*	1361	1299	8.85	1.722	0.985	0.017	0.047	5.773	8.544
24	1217	904	3.54	0.313	0.153	0.143	0.109	5.215	5.933	1522	1043	4.74	0.069	0.077	0.038	0.129	6.430	6.744
26	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
30	1482	1069	5.34	0.042	0.026	0.004	0.045	6.054	6.171	1436	1260	5.26	0.05	0.03	0.01	0.04	5.95	6.07
AVE ALL	1196	1029	6.00	0.54	0.30	0.04	0.07	5.11	6.07	1196	1154	6.10	0.51	0.28	0.05	0.06	5.26	6.17
AVE CC/SJ	1261	1092	6.73	0.81	0.41	0.01	0.08	5.38	6.70	1229	1248	7.11	0.80	0.39	0.02	0.06	5.34	6.60

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CONCORD ENVIRONMENTAL

APPENDIX 5-2

PERCENTAGE CONTRIBUTIONS OF SOURCE GROUPS TO WET SULPHUR DEPOSITION AT SELECTED RECEPTORS PREDICTED BY THE MESOPUFF II MODEL

RECEPTOR	SEASON 1 - SUMMER 86						SEASON 2 - FALL 86					
	CC	NBS	NBN	OOP	BKGRD	TOTAL	CC	NBS	NBN	OOP	BKGRD	TOTAL
3	0.92	1.97	1.52	0.84	94.75	100	2.74	2.53	1.39	1.94	91.40	100
4	1.13	2.82	1.04	1.15	93.87	100	10.87	10.14	0.46	2.38	76.15	100
6	2.62	2.26	0.23	2.06	92.82	100	11.54	11.09	0.19	1.43	75.75	100
7	1.66	7.92	0.67	1.16	88.58	100	2.87	2.69	2.29	1.34	90.81	100
8	1.15	2.85	5.06	0.73	90.21	100	1.88	1.74	7.01	2.09	87.28	100
9	1.11	2.01	1.25	0.78	94.85	100	4.05	3.65	1.68	1.97	88.65	100
12	16.24	6.34	0.08	1.30	76.03	100	20.32	20.05	0.14	0.49	59.00	100
13	7.73	1.81	0.07	1.30	89.08	100	22.71	22.00	0.11	0.48	54.70	100
14	6.74	4.10	0.14	1.64	87.38	100	17.16	16.43	0.23	0.48	65.69	100
15	5.71	4.80	0.12	1.78	87.58	100	12.85	12.42	0.20	0.92	73.62	100
16	5.62	1.99	0.06	1.41	90.92	100	4.87	4.84	0.13	0.89	89.27	100
17	7.91	3.69	0.11	1.79	86.51	100	19.92	19.16	0.18	0.82	59.93	100
18	5.53	3.96	0.22	1.39	88.90	100	9.65	9.42	0.25	0.55	80.13	100
19	9.62	5.61	0.12	1.85	82.80	100	14.84	14.74	0.16	0.74	69.52	100
20	5.81	4.85	0.12	1.89	87.33	100	16.09	15.48	0.19	0.95	67.29	100
21	10.69	3.81	0.09	2.17	83.24	100	2.03	2.12	0.14	1.35	94.36	100
23	8.45	6.14	0.11	1.40	83.91	100	19.49	18.66	0.21	0.43	61.21	100
27	*	*	*	*	*	*	*	*	*	*	*	*
24	1.34	1.16	0.89	1.89	94.73	100	6.57	6.08	0.87	2.00	84.48	100
26	0.90	1.48	2.09	0.61	94.92	100	2.05	1.90	4.23	2.15	89.67	100
30	0.77	0.52	0.05	0.55	98.11	100	0.67	0.64	0.19	1.18	97.32	100
AVE ALL	5.50	3.64	0.63	1.42	88.81	100	11.83	11.42	0.77	1.11	74.88	100
AVE CC/SJ	8.43	4.35	0.11	1.63	85.48	100	15.73	15.27	0.17	0.71	68.12	100

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APPENDIX 5-2 (Cont'd)

PERCENTAGE CONTRIBUTIONS OF SOURCE GROUPS TO WET SULPHUR DEPOSITION AT SELECTED RECEPTORS PREDICTED BY THE MESOPUFF II MODEL

RECEPTOR	SEASON 3 - WINTER 88/89						SEASON 4 - SPRING 89					
	CC	NBS	NBN	OOP	BKGRD	TOTAL	CC	NBS	NBN	OOP	BKGRD	TOTAL
3	0.55	0.64	0.37	0.40	98.05	100	2.78	1.59	1.64	1.42	92.56	100
4	0.92	2.82	0.64	0.46	95.17	100	10.65	5.64	0.33	2.82	80.56	100
6	1.32	0.53	0.08	1.08	96.98	100	8.99	2.71	0.45	1.15	86.70	100
7	1.68	1.42	0.45	0.49	95.96	100	5.02	6.08	0.55	2.15	86.21	100
8	0.31	0.48	0.69	0.47	98.05	100	4.59	1.43	4.13	1.19	88.65	100
9	0.77	1.49	0.48	0.46	96.80	100	3.72	3.83	1.22	3.58	87.65	100
12	3.95	0.39	0.09	0.58	94.99	100	22.09	9.21	0.05	1.14	67.51	100
13	0.64	0.37	0.07	0.37	98.55	100	23.65	4.05	0.03	1.02	71.24	100
14	14.17	4.23	0.15	0.36	81.09	100	15.99	4.15	0.07	1.33	78.46	100
15	4.99	0.81	0.08	0.63	93.49	100	21.60	3.85	0.15	0.87	73.53	100
16	0.58	1.45	0.05	0.35	97.57	100	12.57	3.41	0.20	1.03	82.79	100
17	4.78	0.75	0.08	0.70	93.69	100	14.75	4.93	0.17	0.98	79.17	100
18	13.96	3.74	0.17	0.29	81.84	100	12.14	4.18	0.10	1.05	82.53	100
19	3.97	0.96	0.10	0.57	94.40	100	23.28	4.36	0.10	0.92	71.32	100
20	2.84	0.65	0.10	0.69	95.72	100	15.36	3.50	0.24	1.19	79.71	100
21	1.48	0.30	0.05	0.65	97.52	100	9.54	7.41	0.12	1.19	81.74	100
23	10.84	3.64	0.12	0.54	84.85	100	12.86	10.63	0.09	1.54	74.87	100
27	19.70	1.39	0.09	0.32	78.50	100	6.28	14.20	0.08	1.63	77.80	100
24	1.00	0.37	0.13	0.68	97.81	100	10.39	3.39	5.55	2.16	78.51	100
26	*	*	*	*	*	*	*	*	*	*	*	*
30	0.71	0.39	0.08	0.30	98.53	100	0.52	0.16	0.02	1.01	98.28	100
AVE ALL	4.93	1.42	0.18	0.50	92.97	100	13.05	5.15	0.70	1.40	79.70	100
AVE CC/SJ	7.02	1.65	0.10	0.50	90.74	100	16.34	6.13	0.11	1.15	76.27	100

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APPENDIX 5-2 (Cont'd)

PERCENTAGE CONTRIBUTIONS OF SOURCE GROUPS TO WET SULPHUR DEPOSITION AT SELECTED RECEPTORS PREDICTED BY THE MESOPUFF II MODEL

RECEPTOR	SEASON 5 - SUMMER 89						SEASON 6 - FALL 89					
	CC	NBS	NBN	OOP	BKGRD	TOTAL	CC	NBS	NBN	OOP	BKGRD	TOTAL
3	0.69	0.85	4.10	0.95	93.40	100	2.73	2.44	1.06	3.09	90.68	100
4	3.02	4.63	0.77	0.52	91.06	100	8.44	11.58	2.61	2.05	75.31	100
6	1.11	0.77	0.13	1.06	96.92	100	4.94	1.01	0.56	2.45	91.03	100
7	1.40	1.37	0.76	0.71	95.75	100	2.96	3.84	1.07	2.66	89.47	100
8	0.29	0.61	7.93	0.92	90.26	100	1.65	1.28	6.84	1.07	89.16	100
9	1.14	1.79	2.19	0.53	94.36	100	3.52	5.15	5.91	2.23	83.19	100
12	22.69	2.49	0.11	0.40	74.31	100	15.47	7.49	0.50	0.93	75.60	100
13	10.50	2.84	0.09	0.37	86.20	100	3.94	2.83	0.50	0.99	91.75	100
14	19.84	6.82	0.16	0.36	72.82	100	16.25	12.39	0.52	0.87	69.96	100
15	0.69	1.49	0.11	0.58	97.12	100	14.74	2.38	0.78	1.87	80.23	100
16	5.23	1.31	0.08	0.56	92.82	100	12.97	3.79	0.41	0.92	81.91	100
17	2.91	1.33	0.09	0.53	95.15	100	14.14	3.19	0.70	1.85	80.11	100
18	16.76	5.26	0.21	0.54	77.23	100	16.45	7.21	0.71	1.24	74.39	100
19	5.80	2.01	0.10	0.45	91.64	100	29.96	3.40	0.66	1.65	64.31	100
20	0.92	1.51	0.14	0.94	96.48	100	8.74	3.13	0.79	1.94	85.41	100
21	3.55	0.86	0.06	0.57	94.96	100	1.77	5.10	0.53	2.08	90.52	100
23	21.54	9.01	0.12	0.26	69.07	100	19.75	11.43	0.51	0.74	67.57	100
27	21.69	12.59	0.10	0.23	65.38	100	19.38	5.67	0.54	0.75	73.66	100
24	0.20	0.27	0.42	0.78	98.32	100	1.84	1.80	0.79	3.76	91.81	100
26	*	*	*	*	*	*	*	*	*	*	*	*
30	1.22	0.33	0.06	0.53	97.85	100	1.54	1.26	0.32	0.94	95.93	100
AVE ALL	7.32	3.15	0.98	0.58	87.97	100	10.60	4.84	1.11	1.65	81.61	100
AVE CC/SJ	11.44	4.26	0.11	0.47	83.72	100	14.70	5.53	0.59	1.30	77.88	100

(1) x NOT INCLUDED IN THE ANALYSIS
(2) * NOT AVAILABLE
(3) SOURCES ARE GROUPED TOGETHER AS FOLLOWS:
CC = COLESON COVE TGS ALONE
NBS = SOURCES IN NEW BRUNSWICK SOUTH
NBN = SOURCES IN NEW BRUNSWICK NORTH
OOP = SOURCES OUTSIDE NEW BRUNSWICK
OOP = SOURCES OUTSIDE NEW BRUNSWICK

CONCORD ENVIRONMENTAL

APPENDIX 5-2 (Cont'd)

PERCENTAGE CONTRIBUTIONS OF SOURCE GROUPS TO WET SULPHUR DEPOSITION AT SELECTED RECEPTORS PREDICTED BY THE MESOPUFF II MODEL

RECEPTOR	SEASON 7 - WINTER 89/90						SEASON 8 - SPRING 90 (1)					
	CC	NBS	NBN	OOP	BKGRD	TOTAL	CC	NBS	NBN	OOP	BKGRD	TOTAL
3	0.73	1.34	0.62	0.60	96.71	100	1.58	1.38	1.32	3.14	92.59	100
4	2.75	3.19	0.57	0.51	92.97	100	5.63	8.40	1.01	3.43	81.53	100
6	4.39	2.51	0.26	1.04	91.79	100	5.79	4.91	0.22	1.66	87.43	100
7	2.68	3.27	0.62	0.68	92.75	100	0.25	1.89	1.02	2.17	94.68	100
8	0.28	0.80	0.99	0.37	97.56	100	0.72	1.11	13.77	2.24	82.16	100
9	2.77	3.59	0.72	0.44	92.48	100	1.91	2.82	2.02	2.43	90.82	100
12	2.60	7.44	0.21	0.56	89.20	100	12.44	16.15	0.11	1.02	70.27	100
13	7.69	0.56	0.20	0.41	91.14	100	x	x	x	x	x	x
14	13.59	2.08	0.23	0.56	83.55	100	11.64	9.64	0.15	0.90	77.67	100
15	2.22	4.13	0.25	0.87	92.53	100	11.50	4.84	0.20	1.42	82.04	100
16	0.79	0.64	0.20	0.37	98.00	100	10.76	3.34	0.08	1.10	84.72	100
17	4.97	2.40	0.24	0.81	91.58	100	7.93	11.45	0.16	1.32	79.14	100
18	5.93	5.39	0.33	0.58	87.76	100	5.70	5.20	0.22	0.75	88.14	100
19	1.11	2.76	0.26	0.89	94.99	100	10.56	6.35	0.21	1.17	81.71	100
20	3.84	3.34	0.26	0.91	91.65	100	11.54	4.91	0.23	1.22	82.10	100
21	2.02	1.77	0.23	0.77	95.21	100	23.03	5.10	0.09	1.39	70.40	100
23	17.90	6.82	0.19	0.43	74.66	100	18.39	12.87	0.11	0.91	67.73	100
27	12.89	3.04	0.21	0.42	83.43	100	22.99	18.86	0.09	0.81	57.25	100
24	0.64	1.35	0.43	0.61	96.97	100	1.45	1.36	0.63	2.49	94.06	100
26	*	*	*	*	*	*	*	*	*	*	*	*
30	0.40	0.37	0.12	0.23	98.88	100	0.04	0.02	0.04	1.01	98.89	100
AVE ALL	5.24	2.86	0.33	0.59	90.97	100	10.12	7.10	0.76	1.48	80.54	100
AVE CC/SJ	7.04	3.33	0.23	0.61	88.79	100	14.21	9.33	0.14	1.08	75.23	100

(1) x NOT INCLUDED IN THE ANALYSIS

(2) * NOT AVAILABLE

(3) SOURCES ARE GROUPED TOGETHER AS FOLLOWS:

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NBN = SOURCES IN NEW BRUNSWICK NORTH

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OOP = SOURCES OUTSIDE NEW BRUNSWICK

APPENDIX 5-2 (Cont'd)

PERCENTAGE CONTRIBUTIONS OF SOURCE GROUPS TO WET SULPHUR DEPOSITION AT SELECTED RECEPTORS PREDICTED BY THE MESOPUFF II MODEL

RECEPTOR	YEAR 1						YEAR 2(1)					
	CC	NBS	NBN	OOP	BKGRD	TOTAL	CC	NBS	NBN	OOP	BKGRD	TOTAL
3	1.70	1.74	1.38	1.11	94.07	100	1.12	1.24	2.71	1.51	93.43	100
4	5.50	4.97	0.68	1.73	87.12	100	4.49	6.38	1.10	1.43	86.60	100
6	5.84	3.76	0.26	1.58	88.53	100	3.86	2.27	0.28	1.50	92.09	100
7	2.74	5.63	0.85	1.35	89.44	100	1.69	2.30	0.85	1.40	93.76	100
8	2.18	1.93	4.51	1.05	90.33	100	0.63	0.87	7.63	1.11	89.76	100
9	2.27	2.72	1.20	1.72	92.08	100	1.95	2.82	2.36	1.10	91.77	100
12	17.43	9.20	0.08	1.00	72.29	100	14.80	7.06	0.23	0.67	77.24	100
13	15.52	6.69	0.07	0.86	76.85	100	x	x	x	x	x	x
14	12.75	5.79	0.13	1.13	80.21	100	15.54	7.68	0.26	0.65	75.87	100
15	12.32	5.09	0.14	1.18	81.27	100	6.69	3.05	0.30	1.12	88.84	100
16	7.14	2.86	0.12	1.05	88.84	100	7.85	2.35	0.18	0.76	88.85	100
17	11.77	6.73	0.14	1.18	80.19	100	7.00	4.80	0.26	1.07	86.87	100
18	9.92	4.68	0.17	0.97	84.26	100	11.66	5.65	0.33	0.73	81.63	100
19	14.11	6.03	0.12	1.20	78.54	100	11.88	3.58	0.30	1.01	83.24	100
20	10.36	5.79	0.17	1.33	82.36	100	5.91	3.13	0.30	1.20	89.46	100
21	7.91	4.18	0.10	1.56	86.25	100	9.05	3.19	0.19	1.16	86.41	100
23	12.24	9.47	0.13	1.11	77.06	100	19.42	9.92	0.18	0.56	69.92	100
27	*	*	*	*	*	*	20.15	11.53	0.20	0.55	67.57	100
24	5.28	2.58	2.42	1.83	87.89	100	1.02	1.15	0.57	1.91	95.35	100
26	*	*	*	*	*	*	*	*	*	*	*	*
30	0.68	0.42	0.07	0.72	98.10	100	0.75	0.46	0.13	0.68	97.97	100
AVE ALL	8.94	5.01	0.58	1.22	84.24	100	8.26	4.50	0.84	1.04	85.36	100
AVE CC/SJ	12.15	6.19	0.12	1.13	80.41	100	12.15	5.87	0.25	0.85	80.89	100

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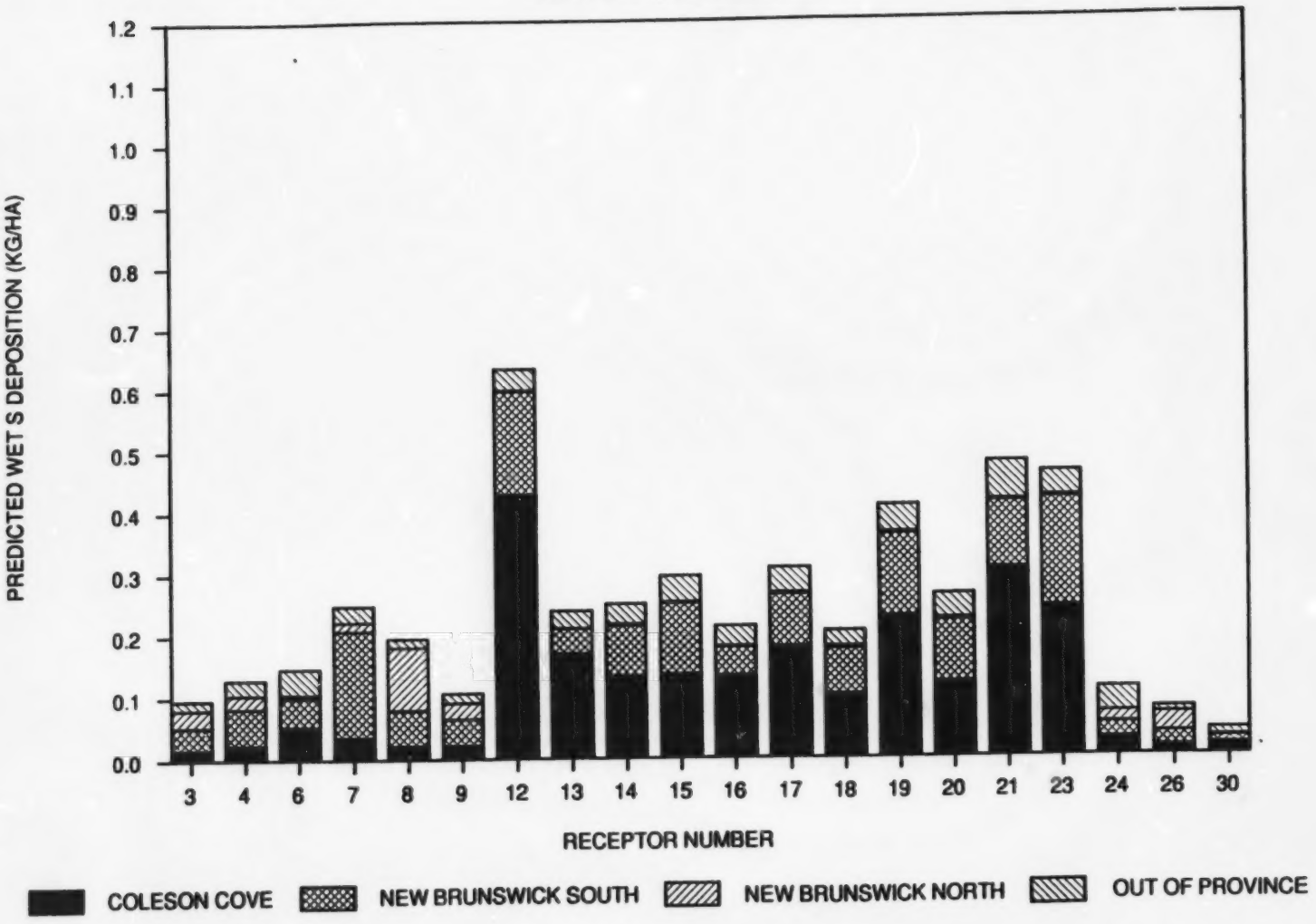
OOP = SOURCES OUTSIDE NEW BRUNSWICK

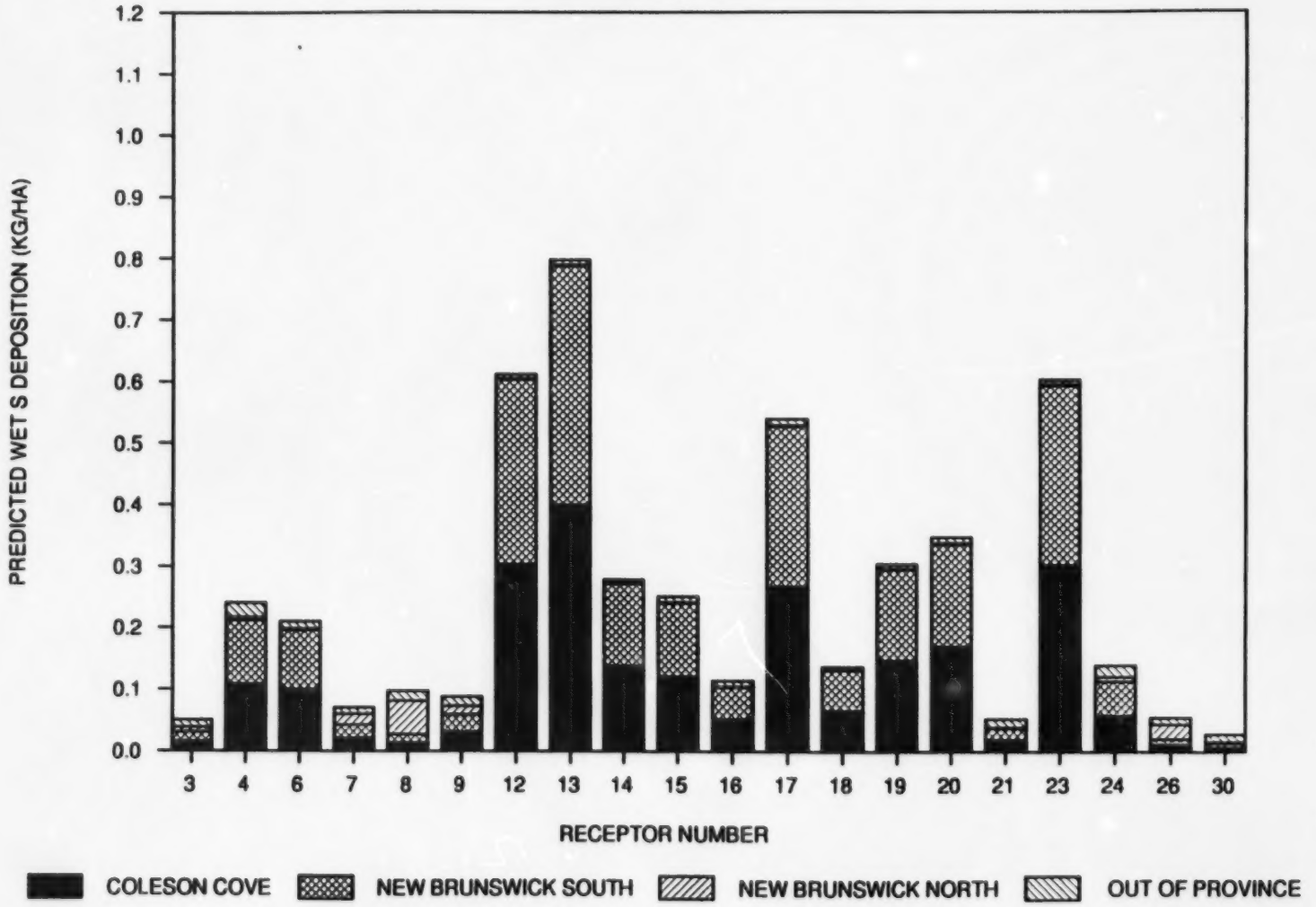
CONCORD ENVIRONMENTAL

APPENDIX 5-3.1
SOURCE GROUP CONTRIBUTIONS
TO PREDICTED INCREMENTAL SEASONAL WET SULPHUR DEPOSITION
SEASON 1, SUMMER 88



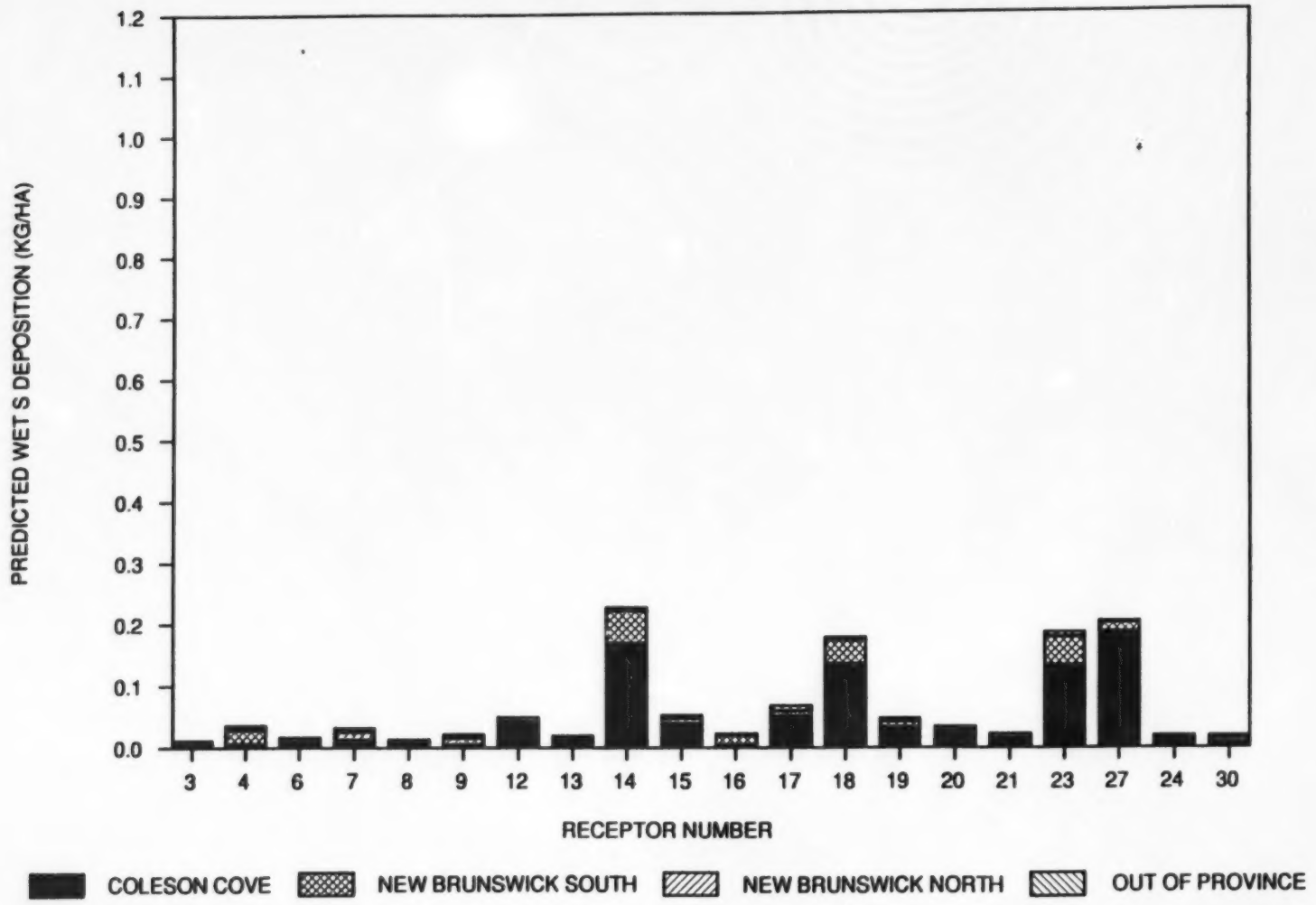
CONCORD
ENVIRONMENTAL

APPENDIX 5-3.2
SOURCE GROUP CONTRIBUTIONS
TO PREDICTED INCREMENTAL SEASONAL WET SULPHUR DEPOSITION
SEASON 2, FALL 88



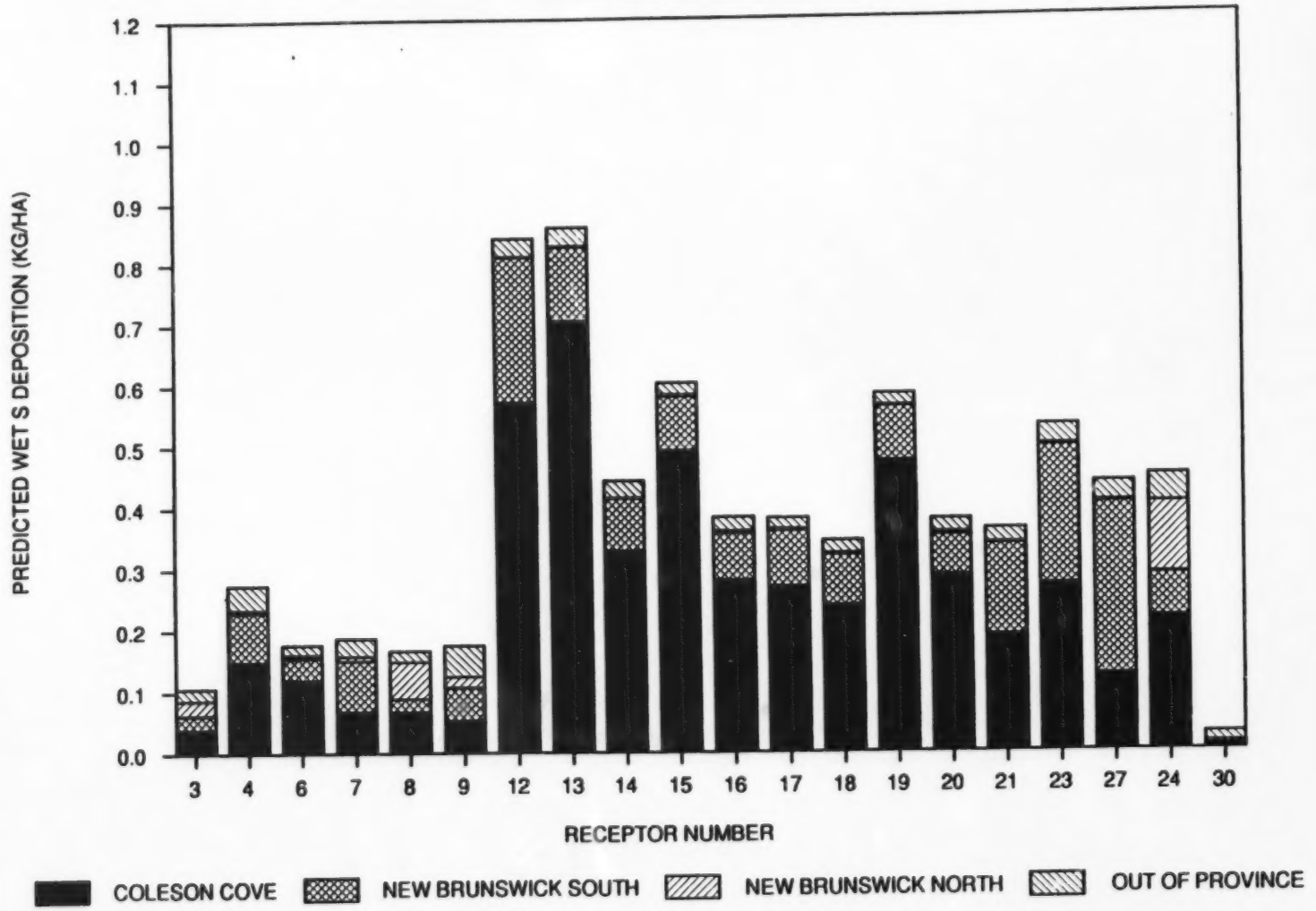
CONCORD ENVIRONMENTAL

APPENDIX 5-3.3
SOURCE GROUP CONTRIBUTIONS
TO PREDICTED INCREMENTAL SEASONAL WET SULPHUR DEPOSITION
SEASON 3, WINTER 88/89



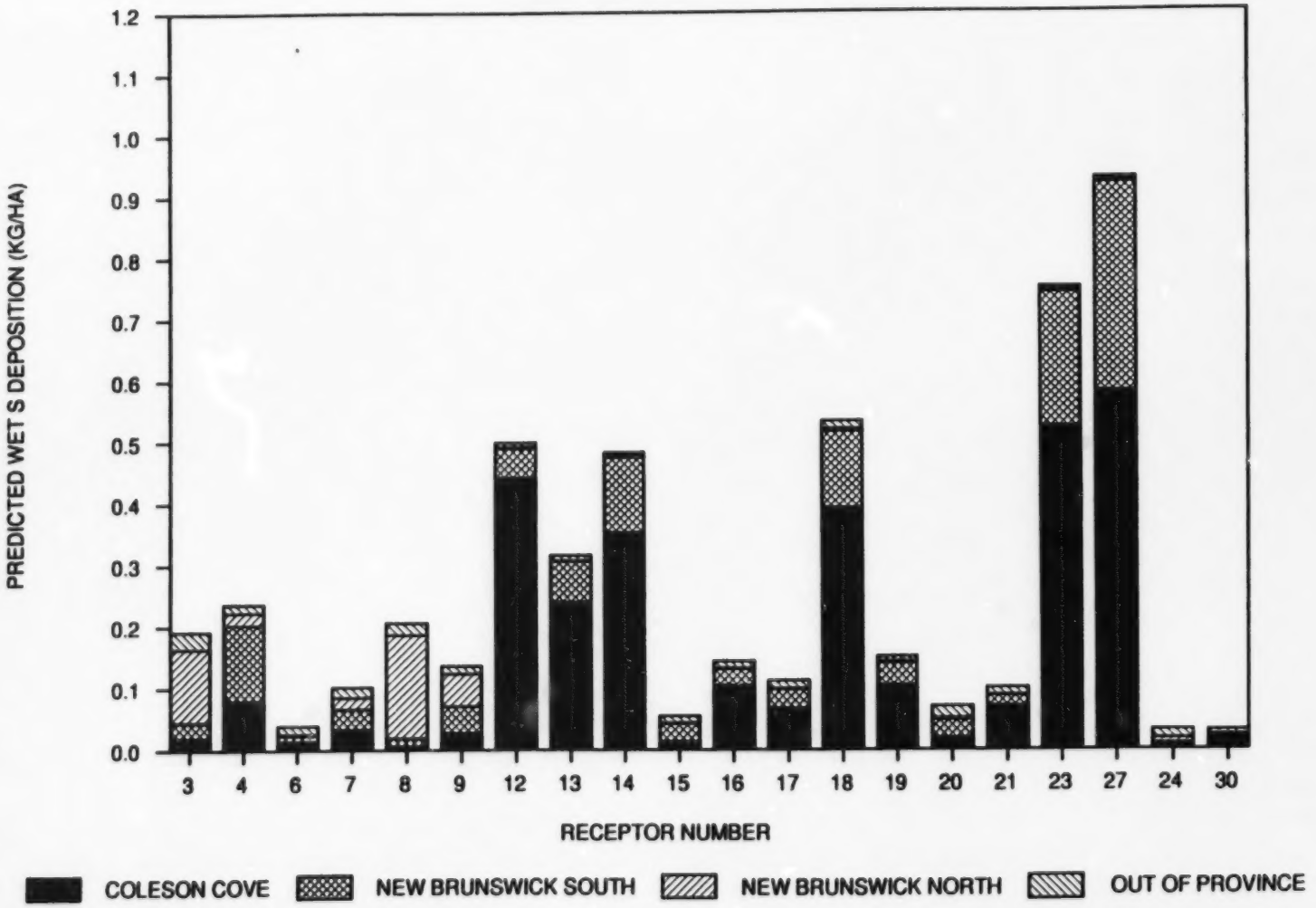
CONCORD ENVIRONMENTAL

APPENDIX 5-3.4
SOURCE GROUP CONTRIBUTIONS
TO PREDICTED INCREMENTAL SEASONAL WET SULPHUR DEPOSITION
SEASON 4, SPRING 89



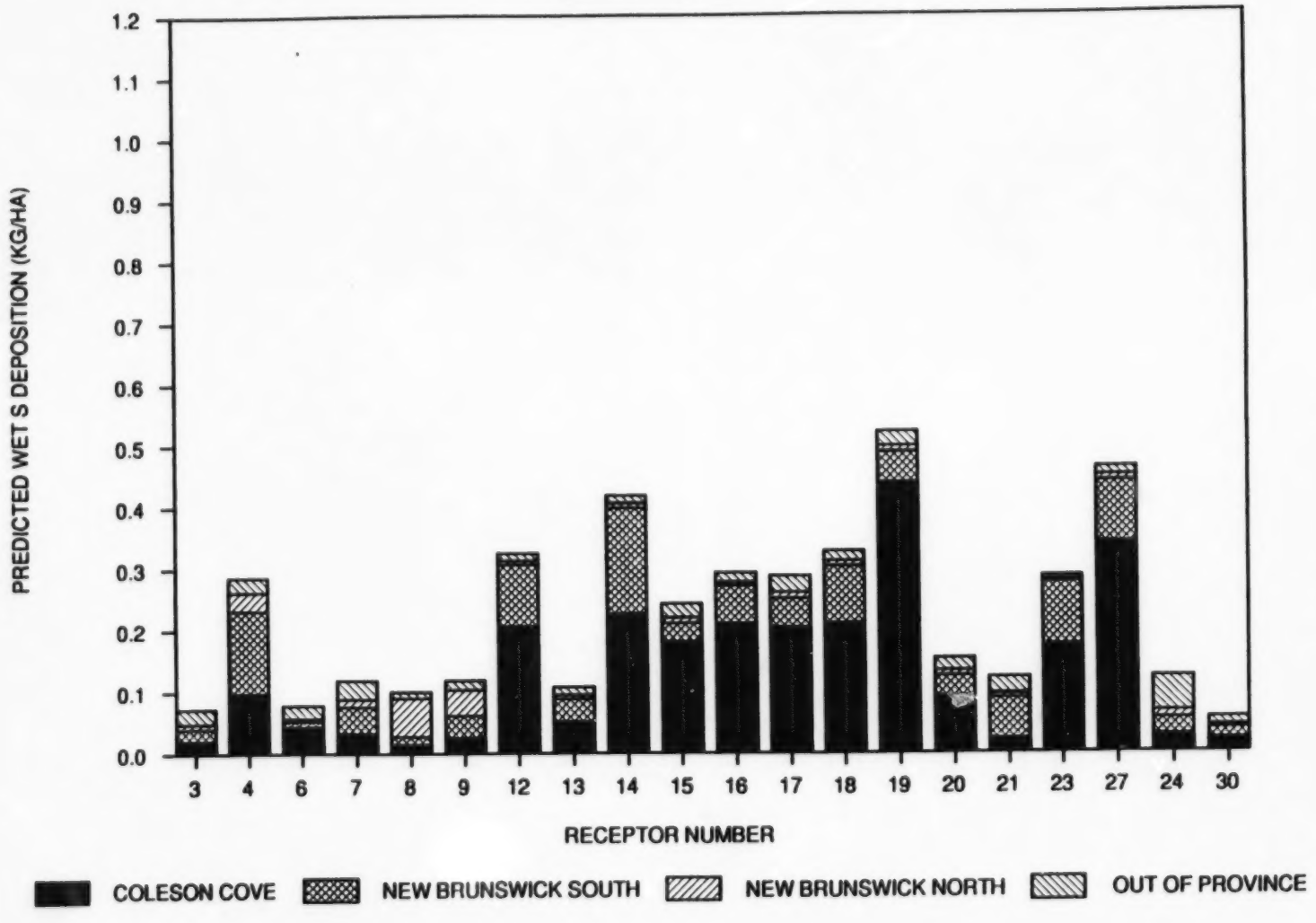
CONCORD ENVIRONMENTAL

APPENDIX 5-3.5
SOURCE GROUP CONTRIBUTIONS
TO PREDICTED INCREMENTAL SEASONAL WET SULPHUR DEPOSITION
SEASON 5, SUMMER 89



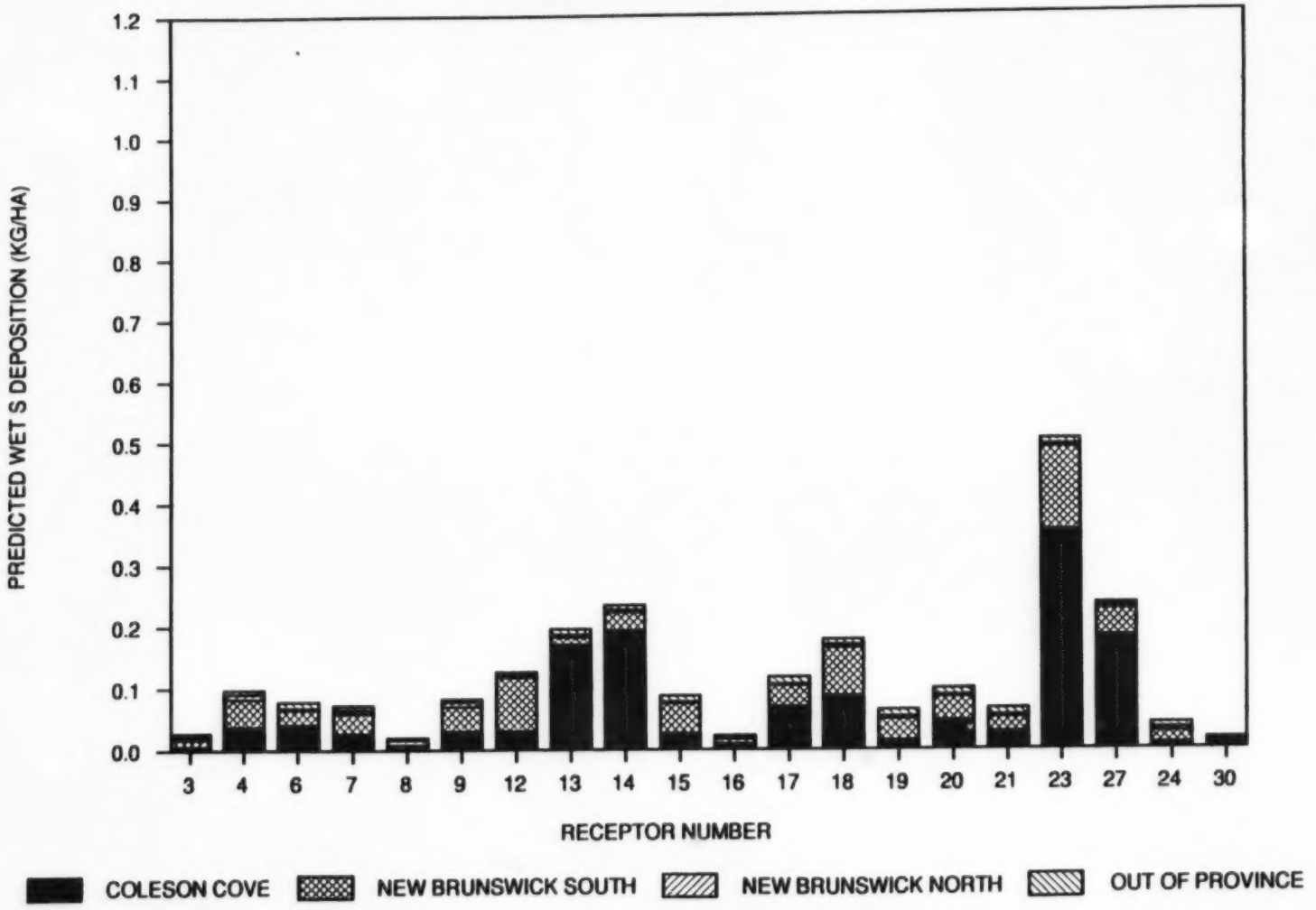
CONCORD ENVIRONMENTAL

APPENDIX 5-3.6
SOURCE GROUP CONTRIBUTIONS
TO PREDICTED INCREMENTAL SEASONAL WET SULPHUR DEPOSITION
SEASON 6, FALL 89



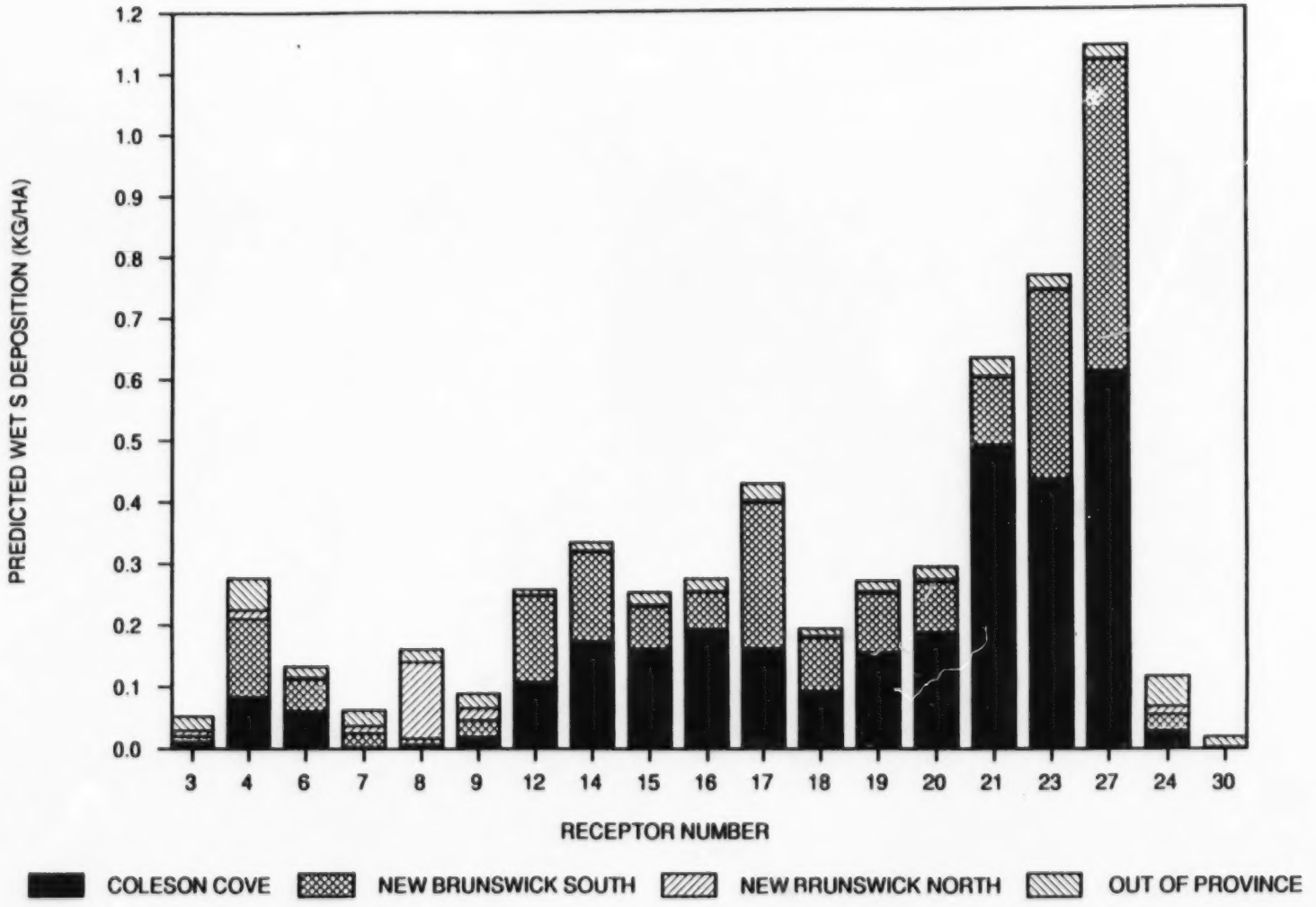
CONCORD ENVIRONMENTAL

APPENDIX 5-3.7
SOURCE GROUP CONTRIBUTIONS
TO PREDICTED INCREMENTAL SEASONAL WET SULPHUR DEPOSITION
SEASON 7, WINTER 89/90



CONCORD ENVIRONMENTAL

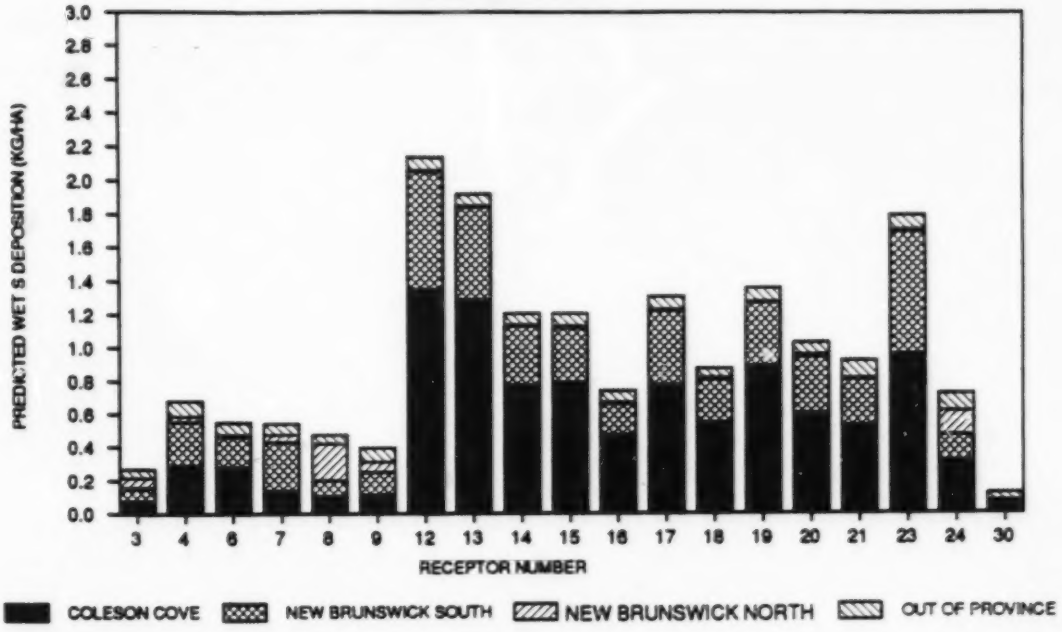
APPENDIX 5-3.8
SOURCE GROUP CONTRIBUTIONS
TO PREDICTED INCREMENTAL SEASONAL WET SULPHUR DEPOSITION
SEASON 8, SPRING 90



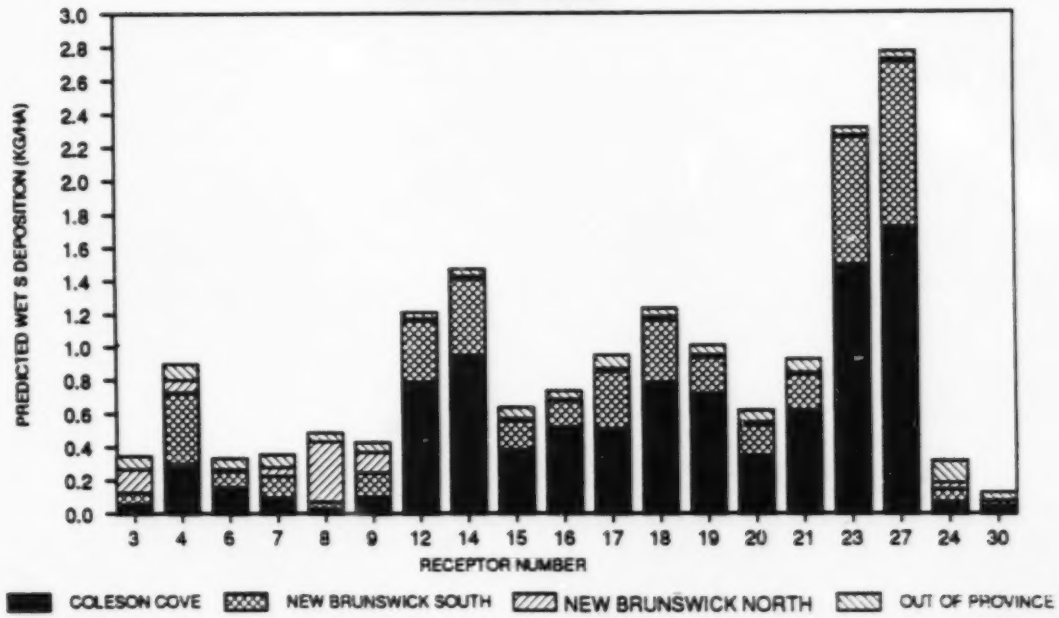
CONCORD ENVIRONMENTAL

APPENDIX 5-3.9

SOURCE GROUP CONTRIBUTIONS
TO PREDICTED INCREMENTAL ANNUAL WET SULPHUR DEPOSITION
YEAR 1, 05/89 TO 05/89

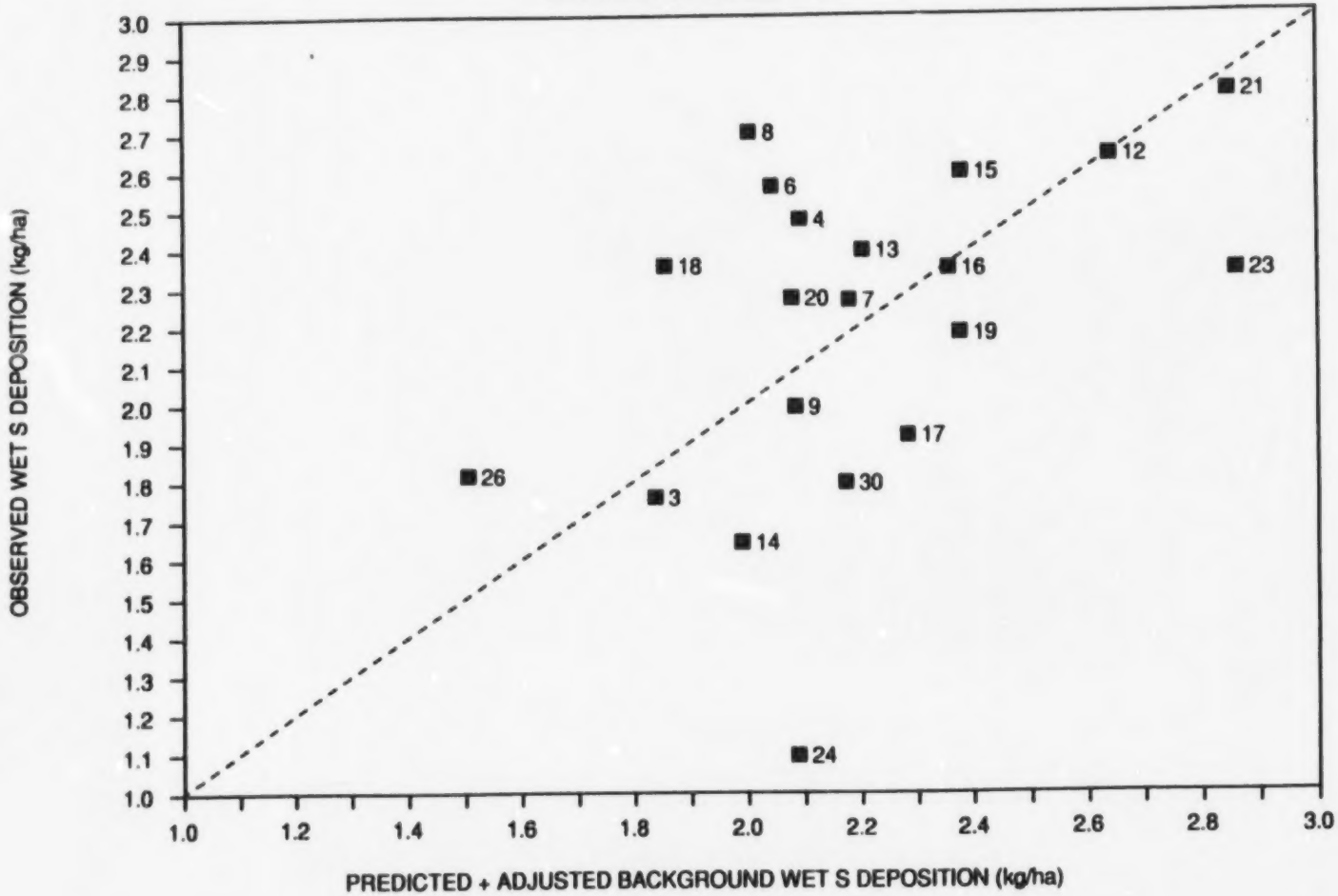


SOURCE GROUP CONTRIBUTIONS
TO PREDICTED INCREMENTAL ANNUAL WET SUPHUR DEPOSITION
YEAR 2, 05/89 TO 05/90



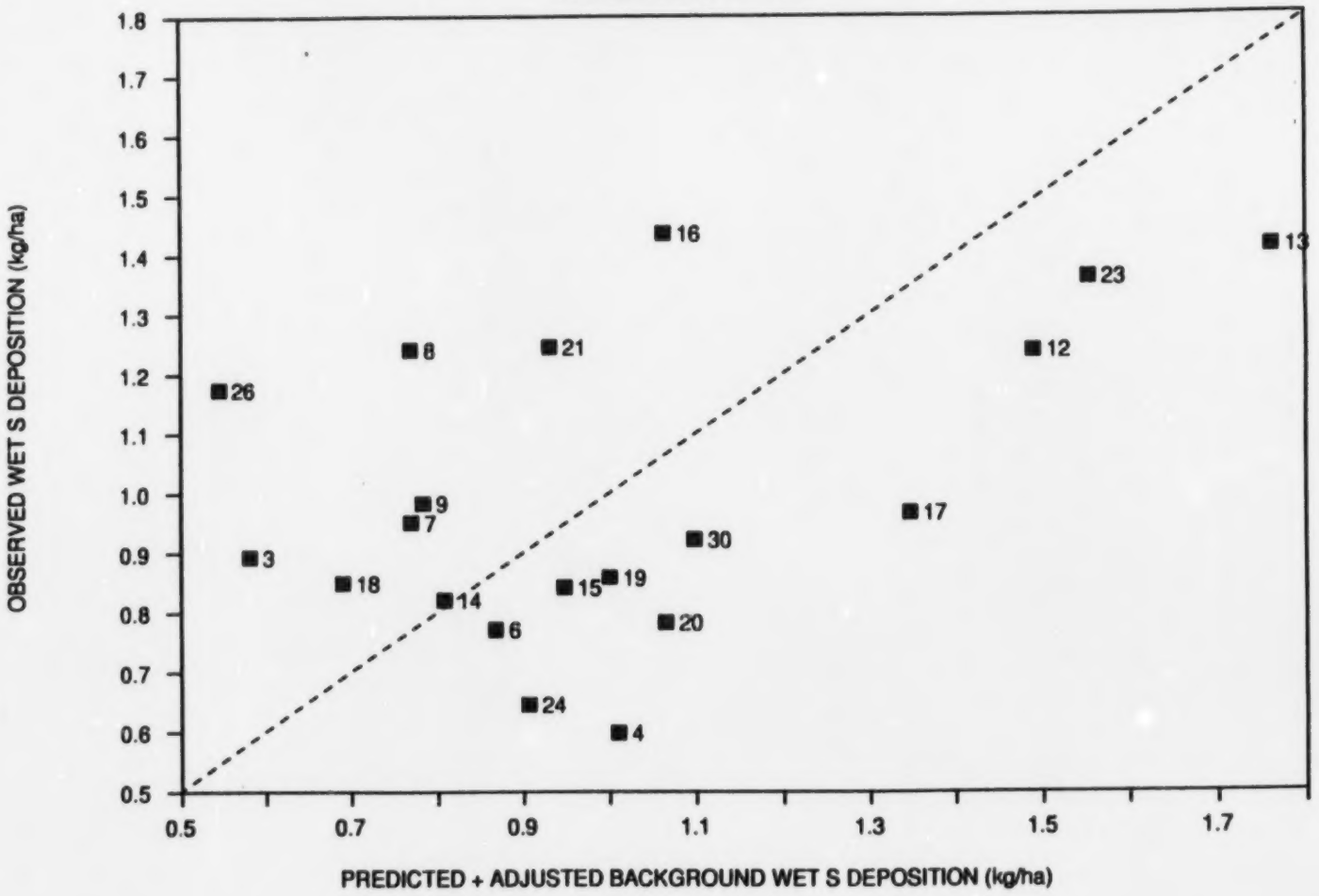
APPENDIX 6

APPENDIX 6-1
SCATTER DIAGRAM FOR OBSERVED AND PREDICTED SEASONAL WET S DEPOSITION
SEASON 1, SUMMER 88



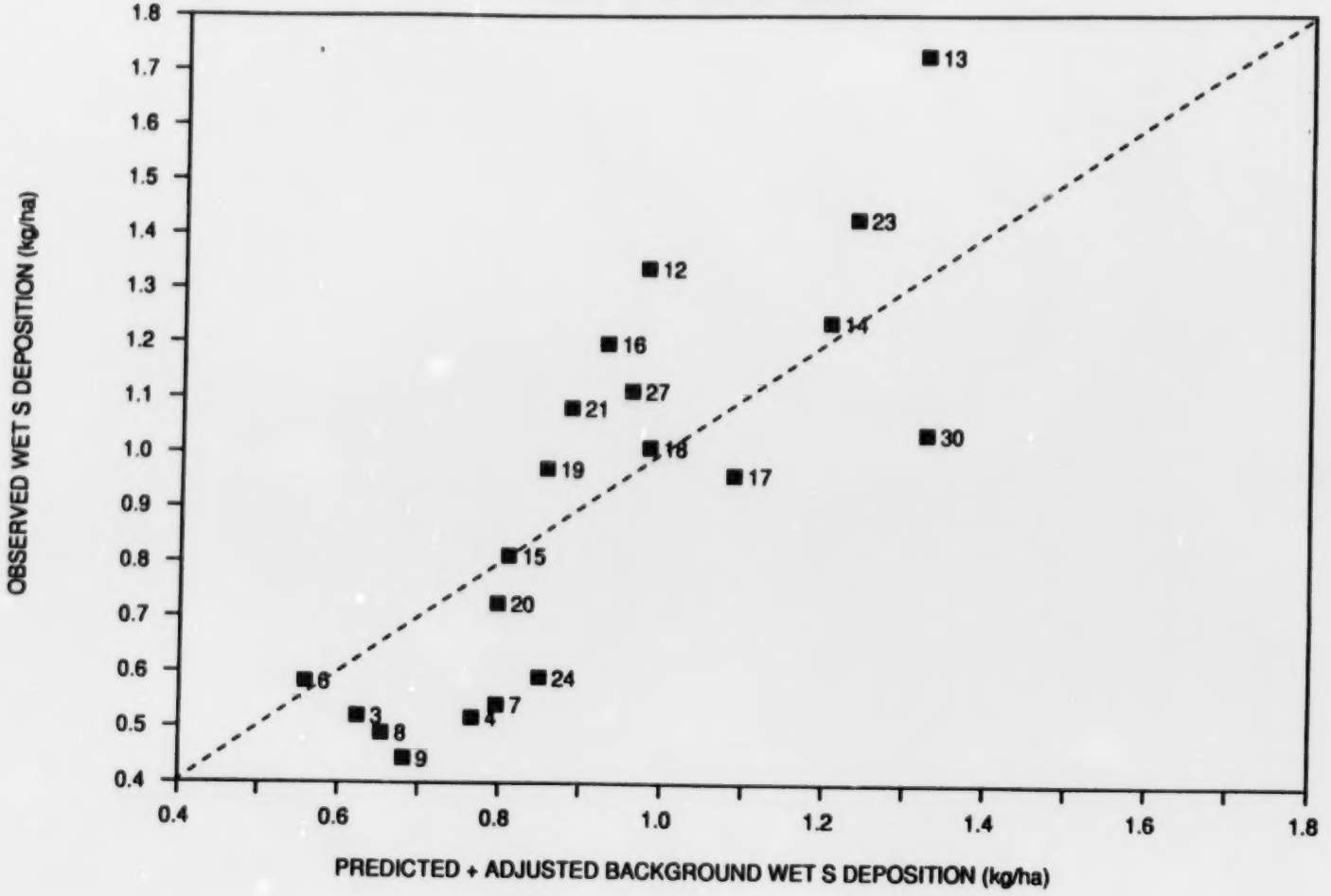
CONCORD
ENVIRONMENTAL

APPENDIX 6-2
SCATTER DIAGRAM FOR OBSERVED AND PREDICTED SEASONAL WET S DEPOSITION
SEASON 2, FALL 88



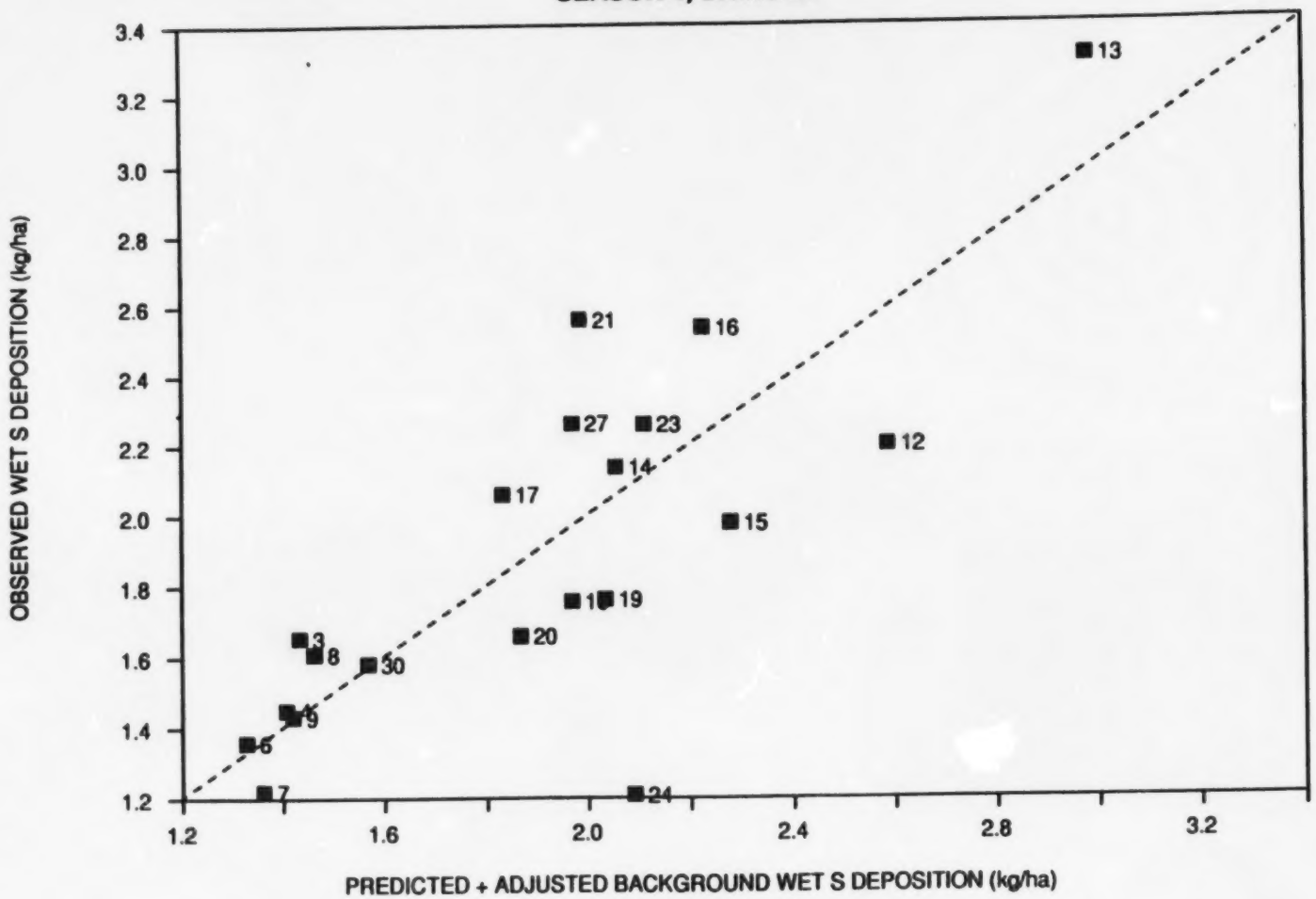
CONCORD ENVIRONMENTAL

APPENDIX 6-3
SCATTER DIAGRAM FOR OBSERVED AND PREDICTED SEASONAL WET S DEPOSITION
SEASON 3, WINTER 88/89



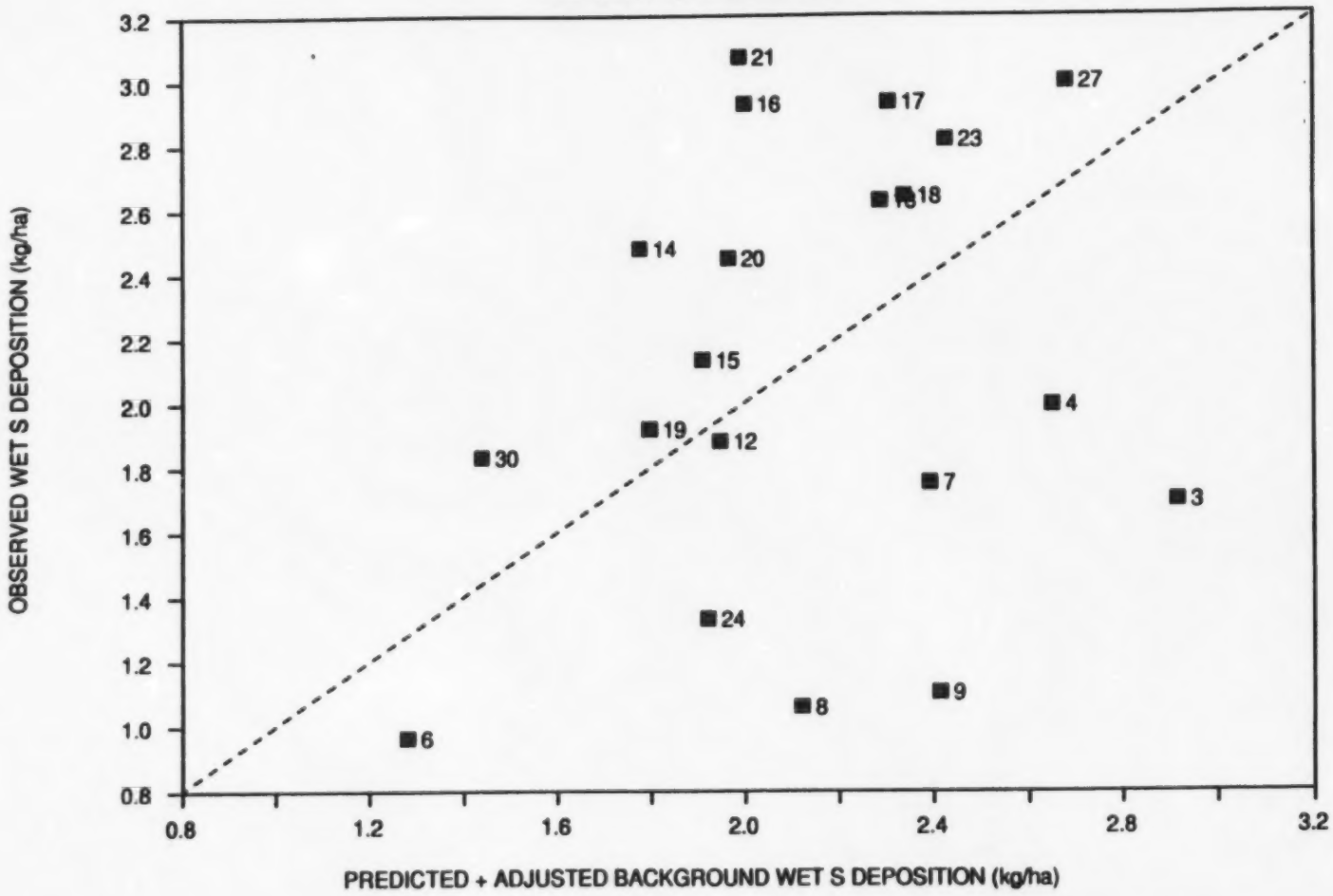
CONCORD
ENVIRONMENTAL

APPENDIX 6-4
SCATTER DIAGRAM FOR OBSERVED AND PREDICTED SEASONAL WET S DEPOSITION
SEASON 4, SRING 89



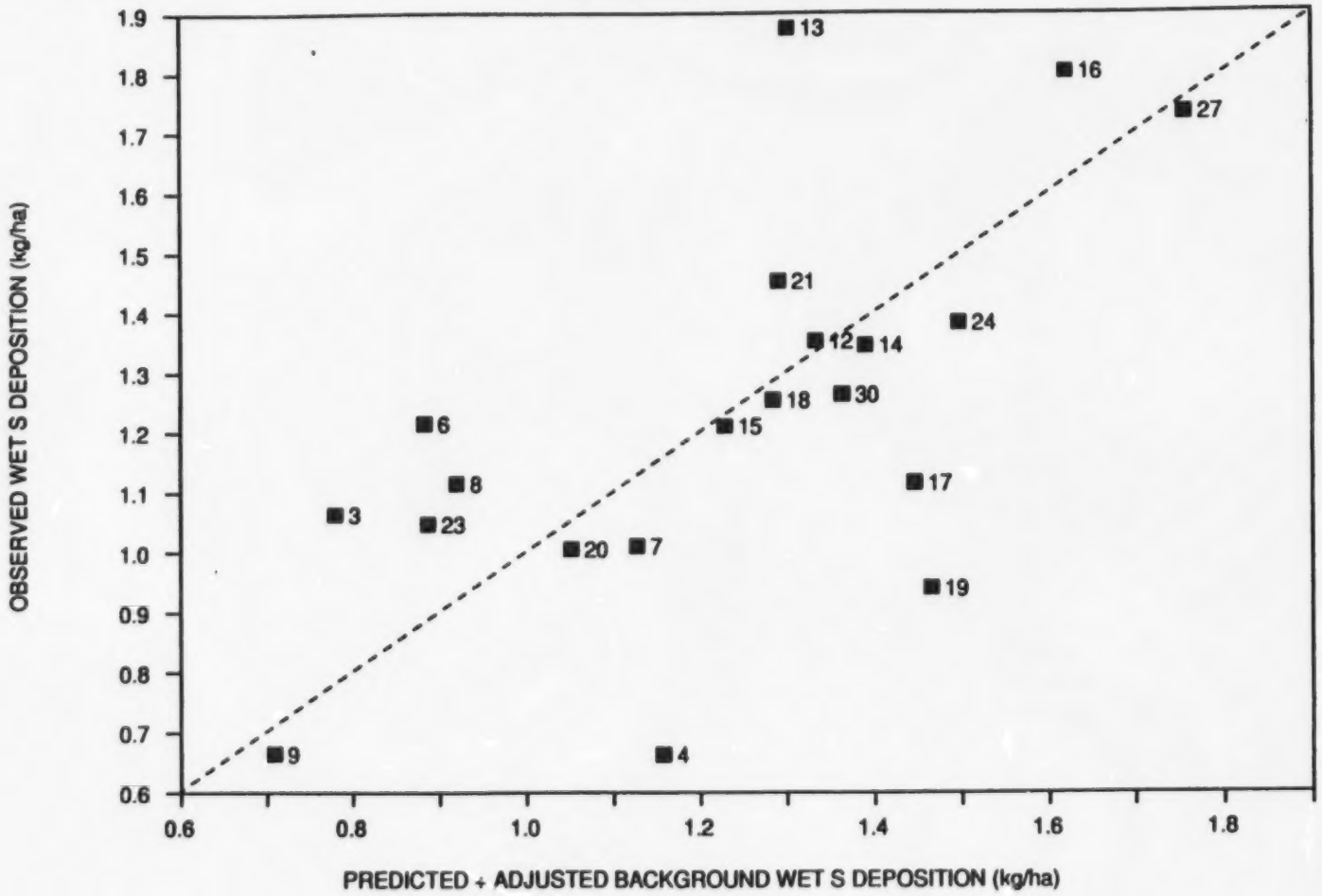
CONCORD
ENVIRONMENTAL

APPENDIX 6-5
SCATTER DIAGRAM FOR OBSERVED AND PREDICTED SEASONAL WET S DEPOSITION
SEASON 5, SUMMER 89



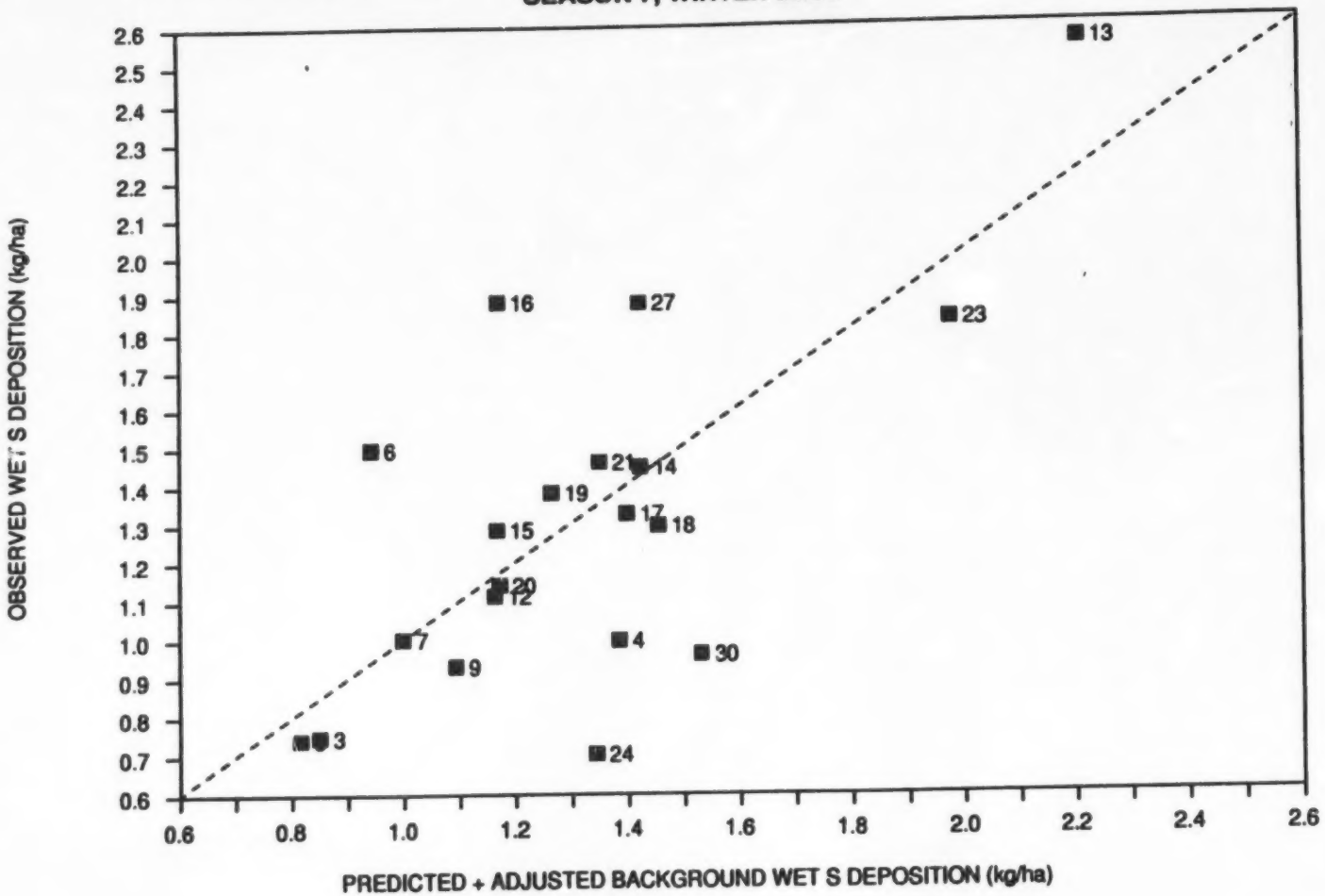
CONCORD
ENVIRONMENTAL

APPENDIX 6-6
SCATTER DIAGRAM FOR OBSERVED AND PREDICTED SEASONAL WET S DEPOSITION
SEASON 6, FALL 89



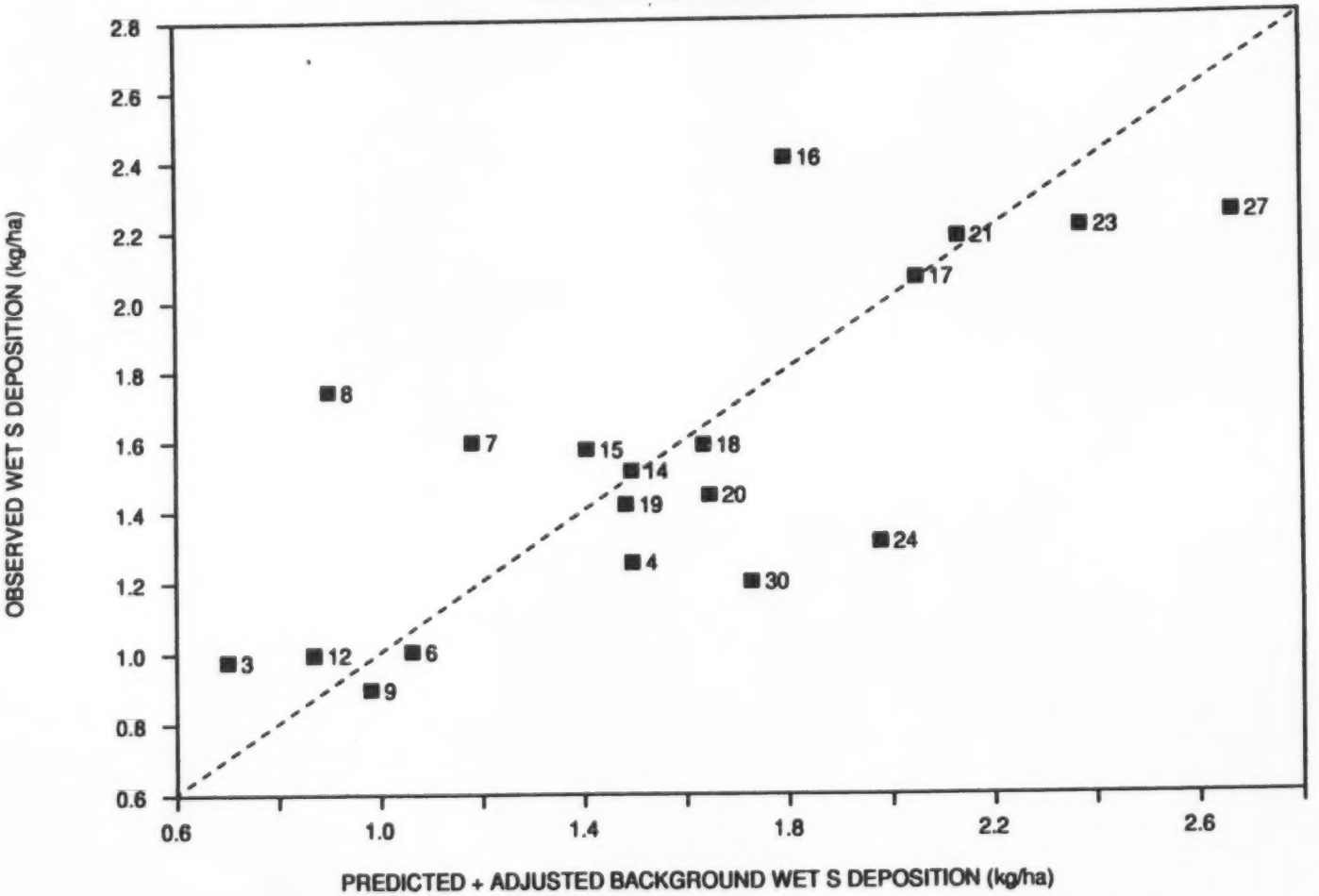
CONCORD
ENVIRONMENTAL

APPENDIX 6-7
SCATTER DIAGRAM FOR OBSERVED AND PREDICTED SEASONAL WET S DEPOSITION
SEASON 7, WINTER 89/90



CONCORD
ENVIRONMENTAL

APPENDIX 6-8
SCATTER DIAGRAM FOR OBSERVED AND PREDICTED SEASONAL WET S DEPOSITION
SEASON 8, SPRING 90



CONCORD
ENVIRONMENTAL